# PROBLEMS OF NATURE.

RESEARCHES AND DISCOVERIES

OF

GUSTAV JAEGER, M.D.

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RESEARCHES AND DISCOVERIES

OF

GUSTAV JAEGER, M.D.,

SELECTED FROM HIS PUBLISHED WRITINGS.

EDITED AND TRANSLATED

BY

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## Part I.—ZOOLOGICAL.



## Part II.—ANTHROPOLOGICAL.

## Part III.—VARIA.

(FACSIMILE.)

Feb 3d. 1875

DOWN,
BECKENHAM, KENT.
RAILWAY STATION
ORPINGTON. S.E.R.

Dear Sir

I received this morning a copy of your work "contra Wigand", either from yourself or from your publisher; & I am greatly obliged for it. — I had, however, before bought a copy & have sent the new one to our best Library, that of the Royal Socy. — As I am a very poor German Scholar I have as yet read only about

40 pages, but they have interested me in the highest degree. Your remarks on fixed & variable species deserve the greatest attention; but I am not at present quite convinced, that there are such independent of the conditions to which they are subjected.

I think you have done great service to the principle of Evolution, which wants better support, by publishing this work. I am the more glad to read it, as I had not time to read Wigand's great & tedious volume. — With my best thanks for the honour which you have done me, & with the greatest respect

I remain Dear Sir

Yours faithfully

Ch. Darwin

Down, Beckenham, Kent, S.E.
*September 9th*, 1869.

Dear Sir,

I lately received, but I do not know by whom sent, a copy of your "Darwin'sche Theorie,"* and I hope that you will allow me to express the admiration and interest which it has excited in me. I must also thank you very sincerely for the manner in which you speak of my works. I am well aware that your generosity leads you to form *much* too high an estimate of what I have done ; but it is deeply gratifying to receive the sympathy of so experienced an observer as yourself. As I am a very poor German scholar I have as yet read only a portion ; but I have already found many observations and incidental remarks of especial interest to me.

The case of the male silver pheasant who was rejected by the females when despoiled of his ornaments will be very useful to me to quote in what I am now writing. I wish you had specified a little more in detail in what manner the plumage was injured. If you have yourself observed any analogous facts with mammals or birds, and would be so obliging as to communicate them, I should feel particularly grateful.

Pray believe me, dear Sir, with my best thanks and sincere respect,

Yours very faithfully,

(*Signed*) CHARLES DARWIN.

P.S.—I will venture to trouble you with one other question on the chance of your having bred last year the *Pavo spiciferus*. I am very anxious to know whether the spurs in this species are developed earlier or later in life, or at about the same period, as in the male of *Pavo muticus*.

It would be necessary to compare birds of the two species hatched last summer, for the spurs are quite small during the first year.

* Compare chapter VI. of this volume.

Down, Beckenham, Kent,
Railway Station Orpington, S.E.R.
*February 3rd*, 1875.

Dear Sir,

I received this morning a copy of your work "Contra Wigand," either from yourself or from your publisher, and I am greatly obliged for it. I had, however, before bought a copy, and have sent the new one to our best Library, that of the Royal Society. As I am a very poor German scholar I have as yet read only about 40 pages, but these have interested me in the *highest* degree.* Your remarks on fixed and variable species deserve the greatest attention; but I am not at present quite convinced that there are such independent of the conditions to which they are subjected. I think you have done great service to the principle of evolution, which we both support, by publishing this work. I am the more glad to read it, as I had not time to read Wigand's great and tedious volume. With my best thanks for the honour which you have done me, and with the greatest respect,

I remain,
Dear Sir,
Yours faithfully,
(*Signed*) CH. DARWIN.

* Compare chapter V. of this volume.

# PREFACE.

DR. GUSTAV JAEGER is well known to the English-speaking world through his hygienic discoveries and researches. But, apart from his reforms in this direction, he has for many years been an active investigator in numerous other branches of Organic Science. He is one of that small group of scientists who, under the leadership of CHARLES DARWIN, thirty years ago, carried the flag of Darwinism from victory to victory; and a number of his own researches opened up new lines of investigation which are of the utmost importance to the general progress of Organic Science.

Dr. JAEGER has written on a great variety of subjects, and it is, of course, impossible to give in detail the observations and investigations of a lifetime in a single volume like this, which, however, comprises most of his important discoveries and researches. Classical investigations like those on *The Influence of Gravitation*, on *The Origin of Species*, on *Sexual Selection*, on *Inheritance*, &c., &c., will rank among the best efforts of research during the Darwinian period, and reveal a mind which is not only familiar with the great mysteries of organic life, but has successfully solved some of the most important of them. In this connection may be particularly mentioned Dr. JAEGER'S discoveries on the influence of the force of gravitation in the organic cosmos.

With so much material to choose from, I have found difficulty in doing justice to Dr. JAEGER'S kind permission to make a selection from his multifarious writings.

The contents of the present volume are divided into the following parts:—

PART I.—ZOOLOGICAL.
PART II.—ANTHROPOLOGICAL.
PART III.—VARIA.

The idea of this work originated with Mr. LEWIS R. S. TOMALIN, to whom I am greatly indebted for the valuable

help and furtherance which he has given to its publication. Mr. TOMALIN has especially assisted me in the literary revision of the proofs, and in the endeavour to aim at idiomatic correctness of diction. For the scientific interpretation of Dr. JAEGER'S ideas I am alone responsible. I take this opportunity of acknowledging the readiness of the various publishers of Dr. JAEGER'S works to allow me to make whatever selections appeared to me to come within the scope of this volume. A list of these works will be found at the end of the book by those who desire to study Dr. JAEGER'S writings in the original.

While great pains have been taken to ensure the faithful rendering into English of the sense of Dr. JAEGER'S writings included in this volume, the translation is not to be understood as, in all cases, a strictly literal one. The scope of the work has, moreover, necessitated a certain amount of abridgment, in which, however, careful regard has been had to the context.

I have tried to render the essays as intelligible as possible to the general public, but in some instances scientific accuracy would have suffered from an endeavour to write in a too popular manner. In order to overcome this difficulty a small glossary is appended, explaining the less familiar terms used by Dr. JAEGER.

In conclusion, I would draw the reader's attention to the two letters of CHARLES DARWIN, which will be found at the beginning of the book. They are of interest both from a scientific and from a historic point of view, revealing not only the scrupulous desire for the investigation of truth, but also the characteristic modesty and simplicity, of the greatest natural philosopher of our century.

THE EDITOR.

# PART I.

# ZOOLOGICAL.

# I.—THE ORIGIN AND DEVELOPMENT OF THE FIRST ORGANISMS.

(1864.)

IN order to explain the origin of animal life on our planet, we must bear in mind that there was a time when no organic life existed on the globe. Secondly, the first living beings must have originated from materials which formed essential constituents in the composition of inorganic matter. Thirdly, we must inquire, what were the general conditions on our planet at the time when the first organic beings made their appearance? It is plain that the surface temperature of the globe must have been reduced to such a low degree that the water—which originally, in the form of vapour, was part of the atmosphere—must have previously cooled down and become liquid. In all likelihood, an enormous ocean was formed, the temperature of which must have been less than 167° F., because this is the highest temperature at which animal life can exist. Thus it is probable that the first organic beings inhabited the water, and this assumption is supported by the following reasons :—

1. All organic beings, and especially the lower organisms, are characterised by a very high amount of water in their body-substance.

2. The fundamental form of all animals is that of the sphere, *i.e.*, the form which every substance in a liquid state is inclined to adopt.

3. It is well known that the vital process consists in an exchange of matter between the organic substance and the surrounding medium, and that for this exchange of matter the substances which react upon each other must be in a liquid state.

The materials of which the first organisms consisted were, without doubt, composed of the same chemical elements of which our present animals and plants consist, the most important being carbon, hydrogen, oxygen, and nitrogen. It is difficult to say

something definite about the molecular structures in which these elements combined, but no doubt carbon—which we must regard as the fundamental basis of all organic compounds—was present as carbonic acid in the atmosphere which surrounded the globe during the time when the latter was in a state of fusion. Therefore, it is evident that *carbonic acid* is the starting point for all those compounds which proved capable of becoming organised, and these compounds have been formed under the influence of water at a temperature lower than 167° F., as before explained. Nitrogen, which also plays such an important part in botany, was doubtless present as a hydrogen compound, viz. : as *ammonia.**

Hence, we have two simple chemical compounds of great importance and simplicity, viz. : carbonic acid and ammonia ; and as the two react upon each other, we may say that *the starting point for all organic life upon our planet, whether animal or vegetable, was an aqueous solution of* AMMONIA CARBONATE.

If we further remember that compounds of sulphur and phosphorus were likewise universally present, we arrive at once at a compound which is in every respect analogous to that known to us as *proteïn*, and which is no longer soluble in water, but separates from it in a liquid state, forming a drop concentrically differentiated and completely analogous to our present organic cytodes and cells.

The next thing we have to examine is the nature of these first organic beings. We can affirm with certainty that these first forms could not possibly have propagated their species by means of a sexual process, because mere cells, or organisms similar to them, can only propagate themselves by division ; and whatever we may assume, it is certain that these first beings were unicellulate animals.

Regarding the question from another side, we come to the same result. These first beings could not, of course, be such as were dependent for their food on other organic beings ; they were neither carnivorous, nor plant-eating, nor parasitic animals ; but must have derived their food entirely from inorganic substances. Hence multicellulate organisms are at once excluded. On the other hand, it has been proved that many unicellulate organisms, *e.g.*, the well-known yeast-cells, can live upon inorganic food ; and in this connection it is very interesting that the inorganic

*It is not impossible that nitric acid also existed in a free state.

compound on which they can exist is nothing else than ammonia carbonate, which we have found to play such an important part at the commencement of all organic life.

We can also arrive at a fairly definite conclusion as to the space over which these first organic beings were probably distributed on the globe. If we try to reconstruct the physical conditions which must have existed in that remote geological age, we come to the result that the chemical, physical, and geological state of things was so monotonous that, in all probability, such compounds could easily make their appearance everywhere on the surface of the globe. There was certainly neither a difference of geographical zones, nor, to any extent, a separation between land and water, nor between fresh water and salt water ; and the temperature and chemical composition of the water, as well as of the atmosphere, must have been almost identical everywhere. This greatly favours the assumption that these simple organic compounds existed in innumerable places, the ocean being peopled by countless organisms which had favourable opportunities to propagate themselves by division. This first population of our planet was, it is needless to mention, one of the utmost monotony, all beings consisting of the above-described unicellulate plasma pieces. Thus the question is excluded as to whether we have animals or plants before us ; we have to go back to those first stages of biology, which are described as "*proto-ontes*" or "*protists*," and which are neither animal nor vegetable, but from which the two organic kingdoms have divided, like two different branches of a tree.

*Haeckel* has proved that the cell itself is not the simplest organic being, but that, as we have mentioned, mere pieces of germ-plasma, which he calls " cytodes," are the simplest forms of organic life. I shall, later on, deal with the question of these simple protoplasmatic beings, to which the monera,* as well as most of the rhizopodes, belong.

Summing up, we find that the first organic beings appeared on the earth under the following conditions :—

1. They made their appearance in the ocean which covered almost the whole surface of the globe, after the temperature of this ocean had been reduced to less than 167° F.

*The discovery of the monera is the result of *Haeckel's* splendid investigations.

2. They probably appeared simultaneously in many parts of the globe.

3. These first beings were either simple protoplasmatic pieces, like the monera, or they were other unicellulate organisms, like the monadines, protococces, astasiaees, &c.

4. The material of which they consisted was doubtless a proteïn compound formed by the reaction of sulphur and phosphorus on ammonia carbonate.

These are the conclusions which we can with certainty draw from our present physical, chemical, and geological information. On a merely empirical line it will never be possible to solve the problem of the beginning of organic life, because we cannot expect to find remnants of these first animals embedded in the rocks of the oldest geological periods. All that has been said in this respect has been found to be incorrect, as the oldest sedimentary formations have suffered such great changes that any traces which might have existed must have been altogether destroyed.

Our next question is: How did these simple organisms develop into multicellulate animals and plants, thus producing the innumerable varieties of forms which characterise the present and most of the previous geological ages? It is evident that none of these forms could have directly originated from inorganic matter in the same way as simple protoplasm; for an organism which owes its existence to sexual propagation can at no time have come into existence without parents, unless we leave the firm basis of natural science and drift into theories of creation. Hence, the one thing that we can state for certain is that all *multicellulates* have developed from unicellulate organisms. This view is supported by the fact that every multicellulate being now living is, in the first stages of its life, unicellulate.

If this assumption is correct, the connecting links between the unicellulate and multicellulate forms must have been analogous to the various forms which our present animals show in their embryonal development.

Palæontology, which has made us acquainted with the plants and animals of previous geological ages, has given us very interesting information in this respect. In the oldest epochs the characteristic features of the then living plants and animals show an unmistakeable

similarity to the embryonal and foetal development of the higher animals and plants of to-day. The oldest fishes, with their skeletons of gristle, are a good example in this respect. Moreover, if our assumption is correct, the most highly organised forms within a geological period must be absent from the previous periods, *and this is actually the case.* Palæontology gives numerous proofs of this: First appear the fishes; in later periods the amphibia and reptiles; and these stand to the mammals and birds, which appear still later, in the same relation as the early stages of embryonal development to the later ones. Similar examples might be given from all those classes of the animal kingdom which are represented by geological fossils.

Thus the correctness of the foregoing view on the origin of the multicellulate animals is established.

## II.—PROTOPLASM.

(1869.)

THE present epoch of natural science is one of unsurpassed importance. Two names are connected with its enormous progress, viz., those of *Charles Darwin* and *Robert Mayer*. *Darwin's* doctrine of descent and of natural selection has shed new light on all organic branches of science ; and *Mayer's* theory of mechanical energy has revolutionized physics, and also, to a certain extent, physiology. Nothing similar has been recorded in the annals of natural science since *Newton* discovered the law of gravitation, and since the undulation theory of light was established by *Young*, *Fresnel*, and others.

The fundamental substance of all organic life is protoplasm, and by his discovery of the monera *Haeckel* has greatly advanced our knowledge of this important subject-matter. My own views on protoplasm and those of *Haeckel* coincide in many respects, while on some points we differ. I think it is therefore of great importance to critically examine what we know at the present time about protoplasm, from which all organic life takes its origin. *Haeckel* is of opinion that the monera have originated through a kind of crystallisation from a mother-lye, and that only the capacity of swelling of the albumin compounds has prevented the formation of crystals. I support this view to a certain extent, as crystallisation may probably have had something to do with the production of the first organisms. I further agree with *Haeckel* that the capacity of swelling of the albumin compounds is one of the most essential points in connection with the formation of organic matter.

But these are only preliminary conditions. *Haeckel* is unable to give any explanation of the origin of life. A piece of albuminous substance, in whatever state of swelling it may be, is neither protoplasm, nor is it living.

To understand this part of the problem, we must first define what the so-called vital forces are. *Du Bois Reymond's* well-known investigations on the nerve and muscle fibres of animals have conclusively proved that the vital forces are essentially *electrical.* If we assume that the substances in question are composed of molecules of electrically opposite qualities, and are embedded in an indifferent conductor (*Ludwig* calls this a *motorial* liquid), we see that these organic tissues are arranged according to the principles of a galvanic volta column.

Four physical conditions must be fulfilled for the production of such a column, viz., two different metals must be present, forming the electro-motors, thirdly, a motorial liquid, and, finally, a conductor between the two electro-motors. The question is now, how far do the above-mentioned living substances physically and chemically comply with these four conditions ?

1. *Physically.*—In the first place we find in nerves and muscles, as well as in every other living tissue, a finely divided molecular substance, possessing a considerable index of refraction ; and secondly, a fundamental substance, which has a smaller index of refraction. This latter substance is not homogeneous, but a mixture of two substances which are not soluble one in the other, the indices of refraction being somewhat different. Consequently, we have three physically different substances, two of which represent the two electro-motors, and the third the motorial liquid. Finally, the conductor which connects the two electro-motors is represented by the liquid which surrounds the nerves and muscle fibres, or, generally speaking, all animal cells.

2. *Chemically.*—In this respect, also, everything is in accordance with the above requirements ; as all investigations on protoplasm, and especially those made by *Kühne*, have proved that protoplasm is not a simple chemical compound, but that we have *a mixture* of several chemically different substances before us. The most important of these substances are, no doubt, the albumin compounds which are always present ; and as we know that more than one albumin compound is invariably present in mixtures of this kind (*e.g.*, *Kühne* found four of them in the muscles of the

frog), we may safely conclude that in this case the two albumin compounds play the part of the electro-motors in a manner closely corresponding to the two metals of a galvanic column.

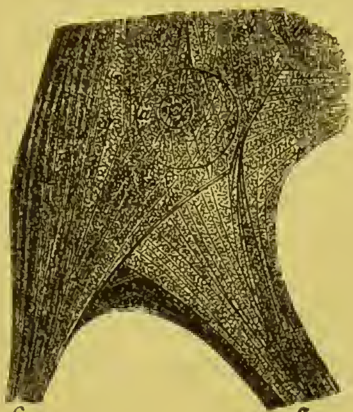
Under these circumstances we can apply *Du Bois Reymond's* researches on the forces of nerves and muscles *to the vital forces in general.* We are supported in this respect by *Becquerel's* investigations on the so-called *electro-capillarity*, according to which the endosmotic, exosmotic, and dialytic processes are likewise due to electric tensions between intra-cellular and extra-cellular substances. Everything is therefore in accordance with my theory of the vital forces, which I formulate as follows :—

*Animal protoplasm is an emulsive mixture of at least three chemically different substances, of which at least two are albumin compounds.*

The electrical tensions produced by the chemical differences are the cause of the sensibility, contractibility, and exchange of matter of the organic substances, in fact they are the cause of the vital forces. Exchange of matter is due to the electric tensions between the protoplasmatic substances and the medium surrounding the protoplasm (*Becquerel's* electro-capillarity). The exchange of matter within the protoplasm is a dialytic process, and the forces which become free by it are thermical, electrical, and mechanical forces. There cannot be the slightest doubt that the characteristics of protoplasm are those of various albuminous compounds, the chemical contrasts of which produce electrical tension. This is in accordance with all that I have previously said about the origin of organic life on our globe. The origin of these compounds—each of which is by itself *absolutely dead*—is a yet unsolved problem of synthetic chemistry ; but after the splendid discoveries of *Würtz* and *Berthelot* in this direction, its solution can only be a question of time.

In connection with this matter we have now to discuss *Haeckel's* view on spontaneous generation. We have seen that he regards the crystallizing process as one of the utmost importance. All that we know about crystallization suggests the idea that the crystallizing body must consist of one simple chemical compound (in this case an albumin compound). But we have proved that

we have to deal with a mixture of at least three albuminates. That this is actually so is shown by the following sketch of a nerve-cell, drawn by *Schultze*.




*a*. Nucleus of nerve-cell.

*b*. Protoplasmatic fibres, granules, and fundamental substance.

*c*. Origin of nerves.

In all kinds of protoplasm we distinguish between the fundamental substance and its granules. *Haeckel* is not quite logical in saying that the monera are perfectly homogeneous, as he himself speaks of their capacity of swelling. This capacity can only exist if we have not merely a fundamental albuminous substance before us, but at the same time an imbibition liquid. The third factor, the granules, which *Haeckel* did not always observe, will be dealt with later on.

We now come to an important fact which has hitherto been altogether disregarded. My views on the origin of the first organisms* lead me directly to the question of organic fertilization. Since *Amici* has explained vegetable fertilization, and since *Keber* has shown how the sperma-cells enter the animal egg, we must regard every fertilization as a *physical* process, *i.e.*, as a mixture of chemically closely-related, but nevertheless unequal, substances. It is only one step more to regard the effects of fertilization as due to electrical tension, as an increase of the vital forces is always noticeable. Fertilization and spontaneous generation are in all probability physiologically one and the same thing, and differ only gradually from each other.

* See chapter I.

In connection with these facts, it is well known that those who cultivate animals and plants have found that continuous propagation within the same family has a very detrimental effect on the constitutional powers of the individuals produced, while what is called the "refreshing" of the blood has the converse effect. This, connected with the fact which *Darwin* has emphasized, viz., that many plants have organs which prevent self-fertilization, proves that the energy of the vital forces produced by fertilization depends on the degree of the chemical differences of the two sexual substances. This is conclusive evidence in favour of my theory of the vital forces.

Dealing further with this matter, we are confronted with that peculiar process of propagation known as *parthenogenesis*. According to the views just expressed on fertilization, parthenogenesis is not only a normal process, but we should be surprised if it did *not* exist. If the descendants of a fertilized cell show a decrease of the electrical contrast in those cells which are situated at the surface, it by no means follows that this is also the case with the cells situated in the interior; and these incline to form a sort of *metagenesis*, producing new cell communities. This process will repeat itself until the electrical contrasts are exhausted, when a fresh act of fertilization is absolutely necessary. This explains why parthenogenesis chiefly occurs with small-sized animals, and why it must necessarily alternate with sexual fertilization.

We see that the origin of life, as well as the different kinds of propagation, are in complete accordance with all that I have explained in this chapter on the nature and properties of protoplasm.

## III.—THE FUNDAMENTAL LAWS OF THE DEVELOPMENT OF THE ANIMAL BODY.

(1875.)

IN my essay on "Symmetry and Regularity, &c.," * I tried to find a connection between the development of animal bodies and certain external influences, and I recommended an examination of all the physical agencies which may have to be considered in this respect.

These were my views before *Darwin's* great discoveries became public, by which so many problems of the organic world have been solved. One of the most important morphogenetic facts is the so-called fundamental biogenetic law, viz., that the ontogenetic development of the individual is a short repetition of the phylogenetic development of the species. The great significance of this law lies in the fact that it supplies a definite connection between the two kinds of development which take place in the animal kingdom. Thus it has become the key to the solution of a great many problems referring to the development of animal bodies. But I completely disagree from Professor *Haeckel's* treatment of this subject, as it means nothing less than an arrest of the progress of science in this important direction. In complete accordance with the conclusions at which I have arrived on symmetry and regularity, Professor *His* has tried to explain the changes of the different forms of embryos, with their folds, curves, &c., by assuming that an unequal tendency of expansion takes place, acting in two directions, which are at right angles to one another. *Haeckel* attacks *His'* explanation of the development of animal forms, asserting that the phylogenetic development is the only cause on which the *total* ontogenetic development of individual animals is based. He says: "Either a direct and causal connection between the ontogenetic and phylogenetic

* See chapter XIV.

development of animals exists, or it does not exist: either ontogeny is a short repetition of phylogeny, or it is not. There is no third possibility! Either we have to adopt epigenesis and descent, or preformation and creation!"

My reply to this statement is, that it looks like a blind belief in a certain kind of preformation to assume that the phylogenetic development is the *preformed* image, according to which the ontogenetic development must by necessity take place; without allowing any influence to the many important external factors, such as the force of gravitation, the limits of space, the admission or exclusion of light, the conditions of heat, moisture, affinity, pressure, tension, &c., &c. Moreover, is it quite superfluous to examine the chemical and physical properties of the ontogenetic protoplasm, and to investigate what influence they may have on the specific growth of the embryo?

I cannot imagine that *Haeckel* seriously intends to deny that the *causæ efficientes* by which the ovum of an animal is developed lie in the ovum itself, and not somewhere else. We all admit, of course, that the composition of the protoplasm of the ovum of any animal is the result of the phylogenetic development of the species through millions of generations; and that there is only one fact which gives us an idea of this whole process of development, viz., the above-mentioned repetition of the phylogenesis by the ontogenesis. But this does not give us the slightest information about the nature of the chemical and physical agencies by which the ovum of an animal is forced to develop itself in one specific direction, and not in any other. It is impossible to discover the nature of these agencies otherwise than by a chemical and physical examination of the ovum in its *present* condition; and we cannot hope to solve the problem of phylogenesis until we know how the protoplasm of any animal ovum has obtained its specific properties. To *fully* understand the ontogenetic development, it is necessary not only to consider the phylogenetic influences, but also to take into account all the causes of the differentiation of the tissues, and of the chemical and physical conditions of development, viz., *the force of gravitation*, *the tension of the tissues*, *the motion and migration of the cells*, *the results of diffusion*, &c., &c. All these factors are entirely disregarded by *Haeckel*, who claims

dogmatic infallibility for the biogenetic law. But science will accept no dogma, neither from friends nor from opponents, and my own investigations show that *His'* above-mentioned investigations, although incomplete, can neither be disregarded nor summarily condemned.

It is evident that the germ-plasma of any animal must possess all the various properties which are essential for reaching a special final stage of animal development, and that consequently the great variety of organisms in the animal kingdom is due to differences of the germ-plasma. It is impossible that germs of different species are equal and equivalent.

This has been misunderstood by many adherents of the theory of descent, who regard the early stages of the embryos of different species as *equal*, owing to the fact that the similarity of the embryos increases in opposite proportion to their age and development. But this is a great mistake : The embryos of two different species are *always specifically different*, however similar their outward appearance may be. *Agassiz** goes so far as to say that the ova of all animals are equal, an opinion which we need hardly discuss, as it is sufficient to consider the enormous variety of the ova of the insects, fishes, molluscs, &c., &c., to become convinced that the differences between the grown-up animals exist already in the ova. That the *apparent* differences in the ova are smaller than those in the grown-up animals is due to the fact that a much greater variety of conditions exist during and after the embryonal development than at the beginning of it. For example, the difference between the ovum of a jelly-fish and that of a vertebrate is seemingly small, while the conditions of development differ enormously ; hence the two ova must from the outset be very different, in spite of their apparent similarity.

We are still far away from the possibility of explaining the embryonal development as a series of chemical and physical reactions which are due to the specific composition of the ova and to the different circumstances of their development. But we can with certainty say that many important differences in the development of animals are due to the chemical and physical differences of the protoplasm of the ova of different species.

*Der Schöpfungsplan. Page 9.

We know that the differentiation of the tissues of different animals is due to certain specific dispositions of their germ-plasma. The plants have cellulosegenous, chlorophyllogenous, and amylogenous dispositions; while, in the animal kingdom, the insects are decidely chitinogenous, and the vertebrates plastogenous and keratogenous. By this symptomatic treatment we obtain a deeper insight into the problems before us, because it leads us to understand, to a certain extent, the connection between the chemical and physical properties of the germ-plasma and the formal development of the animals. This enables us to investigate how far the differences in the principal types of the animal kingdom are due to chemical and physical differences in the properties of their specific kinds of protoplasm. *Haeckel's* plasma theory is incorrect, because as long as we do not know what germ-plasma actually is, it is impossible to explain the grown-up animal by means of the properties of the germ-plasma. *Haeckel** contradicts himself in describing the primary protoplasmatic substance of the monera as homogeneous, and in stating at the same time that the monera invariably contain fine granules which show a yellow colouration when treated with iodine. He seems to believe that these granules are only accessory parts of the protoplasm, *e.g.*, particles of food, etc., and to regard the protoplasm as consisting of a single albuminous compound. But I have previously proved† that *it is impossible, that a single chemical compound can have the properties of the living protoplasmatic substance*, and that it is necessary to have a mixture of *at least three* different chemical compounds in order to produce animal life. Without such a mixture the fundamental physical basis for the explanation of the organic functions is wanting. This is correct, even if we adopt *Hermann's* view, viz., that animal electricity is identical with contact electricity. To this we have to add what we have previously proved, viz., that the granules of the protoplasmatic substance are by no means accessory parts, but form an essential and important portion of animal protoplasm. *Haeckel* will hardly deny this, and he himself states, in speaking of Protomyxa, that not only the quantity of the granules and of the vacuoles, but also the intensity and velocity of the fluctuations of

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* Studien über die Moneren, 1870.

† See chapter II.

the sarcode, depend upon the quantity of the food assimilated by the animal. Hungry individuals, showing a smaller quantity of granules and vacuoles, had also slower and less pronounced fluctuations in their mucous threads. This observation of *Haeckel* makes it quite evident to me that, as such a connection exists between the granules of the body and the energy of its functions, the former must be a vital part of the protoplasmatic substance. It is immaterial in this respect whether the granules are produced by the protoplasm itself, or whether their existence is due to the assimilation of food; as, if the latter be the case, we know that without the assimilation of food the protoplasm will lose its organic properties, and the animal will die. Consequently, the granules, whatever their origin, are essential for the maintainance of organic life. Therefore *Haeckel's* assertion of a homogeneous protoplasm in incorrect.

According to my own investigation, the essential feature in nutrition is the following :—An albuminous compound, apt to swell, is brought into contact with other albuminous compounds which penetrate into the former, and which show, so to speak, an electrical tension to the fundamental substance. If this *process of mixture*, as we may call it, is discontinued, the animal must die from want of food. The sexual fertilization is a process quite analogous to the one described, from which it differs, however, chiefly by the specific properties of the two substances which come into contact with each other. It is evident, from what I have said, why *Haeckel* was unable to solve this last-named problem.

I may summarize my own views on the nature and properties of living protoplasm as follows :—

1. It is neither homogeneous nor without structure, nor is it a single chemical compound. It consists of a transparent substance, apt to swell, in which granules are imbedded; and, chemically, it must be regarded as a mixture of at least three different compounds, of which at least two are carbon compounds containing nitrogen (albuminates).

2. The origin of this protoplasm is due to a process of mixture, and its individual life can only last as long as this process of mixture is not discontinued for any length of time. In this process of mixture we must distinguish between two different functions, viz., nutrition and fertilization.

3. The essential feature in keeping the protoplasmatic substance alive is the fact that the substances which form the mixture differ from one another, and that therefore tension is produced. The motions resulting from this tension disturb the equilibrium of affinity, and produce decomposition of the substances in the presence of free oxygen. Thus forces become free which make themselves noticeable, either as fluctuations within the protoplasmatic substance, or as amœboidal motion and contractibility.

After having investigated the connection between the different embryological forms on the one side, and the chemical and physical properties of the germ-plasma on the other, we will now examine the parallelism existing between the development of the individual and that of its species, as laid down in the above-mentioned fundamental biogenetic law, which has of late been so much attacked. I regard the explanation given by this law of the analogy existing between the embryos of higher animals and the permanent development of lower animals, as an important step in advance for all branches of genetic zoology.

This law is the crimson thread by means of which we may find our way through the labyrinthic difficulties of the relations of the numerous species to one another. But we must not overlook the danger, which nevertheless exists, of losing our way, as the germ forms are not identical with, but only very similar to, their parental forms, *i.e.*, certain characteristic features are equal, but others are quite different, and these latter render the conclusion from the form of the germs to that of the species in many cases uncertain.

After all that I have said, it will be easily understood that we have here to deal with the double influence of *inheritance* and *adaptation.* While, however, the latter can be easily understood, the history of inheritance has found no satisfactory explanation, because the key to this question has not been discovered.* It is only possible to approach this difficult question by again investigating the nature of the germ-plasma.

The fact that *Haeckel* has discovered nothing in this respect, except that he states the parallelism between ontogeny and

* Compare the subsequent discoveries of *Dr. Jaeger* in this respect. See chapter IX.

phylogeny, lies in the circumstance that he really barred his own progress, by assuming that the protoplasm of animals is a *homogeneous* albumin compound. But this is not correct, as we have seen. Animal protoplasm is *not* a homogeneous substance; on the contrary, it is capable of a great many and very important chemical and physical variations, which are of a characteristic kind for every animal species. Men like *Haeckel* and *His*, who have never made researches in this direction, should not therefore feel surprised that they did not succeed in explaining the problem of inheritance.

It is quite true that we have still to learn much about protoplasm and its properties; but this difficulty is no reason why we should not make use of our present knowledge on the subject; and I think that the previous chapters have convinced the reader that we know at the present time a great deal about protoplasm which is well worthy to be used in comparative and critical investigations. So much is certain, whoever desires to promote our knowledge of inheritance must in the first place study the germ-plasma and its properties.

We therefore come to the conclusion that all protoplasmatic dispositions which successively make their appearance in the history of the species, are of such a kind that they may occur in one and the same piece of protoplasm. They cannot, however, appear simultaneously, but only at well-determined periods, when the progress of development has reached a certain organic complication, during the continuance of which they are able to influence the formal course of development.

We see from this fact the mechanical necessity that a certain parallelism exists between the history of the species and that of the individual. The history of the latter divides itself into a series of stages, each of which is governed in its formal development by a well-determined plasmatic disposition, and this disposition is the same which has at some time governed a certain stage of the history of the species. These two corresponding stages necessarily show certain similar features. For example, the phylogeny of the vertebrates contains the stage of the cartilagenous fishes, and this stage is subject to the chondrigenous disposition of the protoplasm. Therefore, in the ontogeny of the bone-vertebrates, this disposition governs that stage of the embryonal development which commences with the appearance of the spinal cord and ends with the substitution

for gristle of bone, *i.e.*, it ends as soon as the osteogenous disposition of the plasma commences to rule. For this reason the embryos of the bone-vertebrates show the principal features which likewise characterise of the structure of the grown-up body of the cartilagenous vertebrates.

Another important fact in this connection is the successive decrease of the amount of water in the embryos at various stages of their development. We shall afterwards see* that such a decrease of water is in close relation to the development of the protoplasm of different kinds or animals, and exactly the same is noticed in examining different embryos. The following interesting table fully explains this statement :—

TABLE X.

*Tadpoles and Frog at various stages of development (according to* BAUDRIMONT *and* ST. ANGE*).*

| | Per cent. of Water. | Per cent. of Organic Substances. † |
|---|---|---|
| Tadpoles, 27th April ... ... ... | 93·37 | 3·55 |
| „ 11th May ... ... ... | 91·24 | 4·56 |
| „ 12th June ... ... ... | 90·15 | 8·43 |
| Frog ... ... ... ... ... | 77·41 | 18·98 |

*Mouse and Sparrow at various stages of development (according to* BEZOLD *and* BAUER.*)*

| | Per cent. of Water. | Per cent. of Solid Substances. |
|---|---|---|
| Embryo of Mouse (size ½ inch) ... | 87·2 | 12·8 |
| New-born Mouse ... ... ... | 82·8 | 17·2 |
| Mouse, 8 days old ... ... ... | 76·8 | 23·2 |
| Grown-up Mouse ... ... ... | 70·8 | 29·2 |
| Very young Sparrow ... ... ... | 78·9 | 21·1 |
| Young Sparrow, somewhat older ... | 73·7 | 26·3 |
| Grown-up Sparrow ... ... ... | 67·0 | 33·0 |

* Chapter XII. † The figures for the *salts* are omitted in this list.

That fish and many other vertebrate animals show a continuous decrease in the proportion of water, so long as the embryonal development proceeds, will be known to any one who has made experiments in this respect; the younger the embryos are, the softer their bodies appear to be. I am of opinion that these facts constitute a parallelism which is of the utmost importance for the explanation of that part of the biogenetic law dealing with inheritance.

We are now in a position to formulate the behaviour of the various plasma dispositions during the progress of the embryological development, as follows:—*The morphological activity of every protoplasmatic disposition depends on a certain amount of water in the protoplasm of the embryonal cells.* Therefore, each of these various dispositions can only act during a certain period, when the proportion of water is that which it requires for its action. Thus the activity of each of these plasma-dispositions is limited in a double sense. First, a certain stage of the development of the embryo must be reached; and, second, the proportion of water must be fixed, and always the same.

This insight into that part of the biogenetic law which deals with inheritance enables us to shortly mention the question of *adaptation.* The most important point in connection therewith is the problem how new protoplasmatic dispositions can be added to the existing ones. There must be a mutual adaptation between the new and old dispositions. They, like everything else in the organic world, are subject to the law of natural selection, where the victory always remains with the strongest. The struggle in this case is principally in respect of space.

It will be admitted that what I have said in this chapter includes a number of important modifications of the fundamental biogenetic law, and I am glad that I have been able to add something to the classical investigations of *Baer*, *F. Müller*, *Darwin*, and *Haeckel* on this subject.

## IV.—THE PRINCIPAL LAWS OF THE DIFFERENTIATION OF THE ANIMAL BODY.

(1875.)

WE have hitherto connected the differences in the development of various animals with the peculiar differences of the chemical and physical properties of the various kinds of germ-plasma. Our next step will be to apply what we have found to some of the principal types of the animal kingdom. The present incomplete state of our knowledge permits us only to deal with large groups, widely differing from one another, because the differences in the germ-plasma of the more closely related animal groups have not yet been investigated.

Secondly, we have to explain the reason that the ontogenetic development of every animal is a repetition of the phylogenetic history of its species, as merely to state the empiric existence of such a law is not sufficient without explaining its cause.

It is necessary to find the fundamental basis of the differences of germ-plasma. This we shall do by examining the differences which separate the protoplasmatic germs of the lower animals from those of the more highly developed groups.

The first difference which we have to examine is that between cell animals and protoplasmatic animals. The protoplasm of the former shows a kind of concentric differentiation, by forming a nucleus in the centre, this nucleus being at least once, and in many cases two or three times, subdivided. I define this as the *nucleogenous* or *endodifferential* property of the germ-plasma in question. Protoplasmatic animals, on the other hand, form no cells, their protoplasm being either entirely *indifferential*, *i.e.*, showing no trace of a concentric differentiation, or merely *exodifferential*, having a kind of skin or bark (exosarcoma), and in the interior a liquid substance (endosarcoma). The difference between differential and indifferential protoplasm is principally one of mobility. The protoplasmatic animals show an almost uninterrupted fluctuation

of granules, and this proves that their substance is constantly in a state of being mixed. No tendency to a concentric differentiation is in such a case observable ; but as soon as the mobility decreases, concentric differentiation sets in, and an exosarcoma is likely to be developed. That this difference of mobility is not only the cause of the exosarcoma and endosarcoma, but also of the differentiation into nucleus and protoplasmatic mantle, is proved by the fact that the plasma of the amoebæ, which have a nucleus, in no case reaches the same degree of fluctuation as that of other protoplasmatic animals without a nucleus.

A further important modification, by which the cellulate animals and the protoplasts are divided into different groups, is the difference between *capsuligenous* and *a-capsuligenous* protoplasm. Probably this modification is also due to a temporary decrease of the contractibility of the protoplasm, as it always occurs when the protoplasm is in a state of inactivity. We must remember that when the number of granules in the plasma is small there is little organic energy. But so soon as the number of granules increases, a development of organic energy takes place, the greater number of granules being at the same time an obstacle to the *mechanical* effect of this energy.

Moreover, the *size* of the granules is a feature of great importance, as large granules obstruct the active *physiological* energy of the protoplasm. Large-sized granules are therefore comparatively inactive, while those of smaller size (having in proportion a larger surface, and therefore more contact with the fundamental substance) produce a greater amount of physiological energy. Furthermore, when the granules are irregularly distributed in the fundamental substance, the changes of form incline to be irregular and of an amoeboid character. But whenever we find a regular arrangement of them, as, *e.g.*, in cross-striped muscles, we notice linear reduction only ; or, if the granules are exceedingly fine, as in neuro-protoplasm, no change of form is perceptible, and only the active physiological energy is developed.

Another physiological point of great importance is the degree of imbibition of different kinds of protoplasm, as a higher degree of fluidity of the fundamental substance produces greater fluctuations and changes of form.

As regards the chemical side of the question, those granules which consist of albuminous compounds are of the utmost importance, because in all probability they alone are the bearers of the vital functions, while fatty substances, colouring matters, &c., &c., are only of secondary importance.

From what I have explained as to the connection between the physical properties and the mobility of the protoplasm, it follows that the important change from the indifferential protoplasm to the differential and capsuligenous modification, is due to a physical change which diminishes the mobility of the protoplasmatic substance. This is in accordance with the observation that many unicellulate animals change periodically between a free and active and a sedentary and inactive state. The latter is characterised by the increased number, and the larger size, of the granules.

I have now to explain the chief differences between unicellulate and multicellulate animals. The reason why both of these groups exist, and are distinctly separated from each other, is, that the protoplasm of the former is more amoeboidal, *i.e.*, more mobile, than that of the latter. On account of the physical changes above described, the multicellulate animals are characterised by a decrease of the protoplasmatic energy. For example, the capsuligenous disposition of certain kinds of protoplasm supports the production of multicellulate animals. But this factor alone is not sufficient to explain the difference, as many unicellulate animals also show a temporary capsuligenous disposition, which only ceases when a process sets in which we may properly compare with starvation. By this process the protoplasm regains its former energy and mobility.

Capsulation is only efficient when the capsules are very solid, as is, *e.g.*, the case in the development of the ova of many unicellulate animals. In these instances the separation of the different parts is prevented by various causes, viz. :—

1. The capsule is a mechanical obstacle which holds the different materials together.

2. The shells of the ova protect the embryonal cells from the surrounding mechanical influences.

3. The protoplasm of the monera, rhizopoda, and other unicellulate animals is surrounded by water, while those embryonal cells which are enclosed in a shell are surrounded by a liquid which

contains various organic substances in solution, the latter condition being, of course, much more favourable than the former to keeping the embryonal cells together.

Thus we see that a comparatively small change in the chemical and physical properties of the protoplasmatic substance exercises a very great influence on the development of the organization in animal life, as it is the direct cause of the accumulation of cells, *i.e.*, of the multicellulate animals. We may well express this difference by saying that unicellulate animals have a *mobile*, multicellulate animals an *adhesive*, protoplasm. This is a further confirmation of what I have said above about the important part which the plasma-granules play.

We must now examine the characteristic features of the unicellulate animals, especially those of the amoebæ, flagellata, and ciliata. Here we have principally to deal with the mobile plasma-threads, pseudo-feet, and whip-cells. I am inclined to think that the difference between the two last is produced by the exo-differential disposition of the protoplasm of the ciliata, as the differentiation of exosarcoma and endosarcoma is admitted by all who have investigated this group of animals. This explanation is at the same time the key to the origin of the whip-cells, because the exosarcoma is porous, and fibres of the softer substance with which the interior is filled creep forth through all the pores. This is either due to a contraction of the cuticula, or to an increase of the substance in the interior, or to the fluctuations in the interior, as is *e.g.*, the case with the pseudopoda of the foraminifera. A further cause of the differentiation between the amoebæ and the ciliata is the difference in the mobile energy and mobility of the protoplasm, because, so soon as these decrease, the tendency to differentiate is enhanced. The more active modification is that of the amoeboid-differential protoplasm, while the more passive modification is that of ciliogenous-differential protoplasm. The most active modification of all may be called indifferential or super-amœboidal, which characterises the rhizopoda and monera.

We now come to the flagellata. *Haeckel's* observations of the contractibility of the whip-cells of the entodermatic layer of the calcareous sponges prove conclusively that the whip-cells are a different stage from the plasma-threads and the pseudo-feet. This

view is supported by the bodily development of the flagellata, which hold an intermediate position, as their exosarcoma and endosarcoma are much more conspicuous than is the case with the amoebæ, while they are by no means so highly developed as are the corresponding parts of the ciliata.

Consequently, the flagellogenous-differential protoplasm must be considered as the connecting link (both as regards active energy and differentiation) between the other two modifications.

From these facts I draw the important conclusion, that *a direct connection exists between the characteristic differentiations of the lowest groups of animals and the gradual decrease of the physical energy of the protoplasmatic substance of which they consist.*

Proceeding to the multicellulate animals, we have already seen that the existence of these animals is due to a further decrease of the active protoplasmatic energy. Comparing the egg-plasma of a multicellulate animal with that of a rhizopode, we notice a remarkable difference in the degree of pellucidity, viz., the protoplasm of the rhizopode is much more homogeneous, and contains a great many exceedingly fine granules, while the multicellulate protoplasm appears turbid, and contains larger granules, which differ among themselves in size and composition. This protoplasm is characterised by its great inactivity, as compared with the amœboidal protoplasm of unicellulate animals. The consequence is, that the embryonal cells associate together, forming a small cell-heap, which *Haeckel* appropriately calls *morula.* The morula develops into the hollow *blastula*, and the latter into the *gastrula*, as is well known. The gastrula is the most important stage of the multicellulate ontogenesis, and *Haeckel's* gastrea theory has been strongly confirmed by the discovery of living animals which are completely identical with the ontogenetical gastrula. The blastula develops into the gastrula by the resorption of the contents of the former. The great question is, which property of the protoplasm produces this resorption? We know that volvocines and catallacts have neither resorption nor gastrula, it being evident that the surface-cells of these animals allow the surrounding water to penetrate into the interior. Hence it is probable that the blastula stage will disappear so soon as none of the surrounding liquid can penetrate into the interior.

But what is the reason that gastruligenous protoplasm becomes less pervious? There are only two possibilities, viz., either the embryonal cells close firmly together, *i.e.*, the *adhesive* properties are increased, or the protoplasm itself attains to a more solid condition. In any case, this great step in the direction of a higher development is evidently due to a simple metamorphosis of the embryonal protoplasm.

The next step in the differentiation of the multicellulate animals is the division into coelenterata and enterata. While the former remain stationary at the gastrula stage, usually developing only the exodermatic and entodermatic layers, the latter develop a perigastrium which is filled with what I may term the primary liquid of nutrition, corresponding to the lymph of the vertebrate animals. This liquid being a product of the protoplasm of the enterata, I call it lymphagenous protoplasm, while the protoplasm of the coelenterata is of an a-lymphagenous nature. If we inquire into the chemical and physical causes which render animal protoplasm lymphagenous, we shall find that a further increase of the adhesive properties and of the differentiation is the most likely reason.

As this is a very important point, it must be explained in detail. The ontogenesis of the coelenterata teaches us that these animals use all their embryonal cells for the production of the exodermatic and entodermatic layers; and in a few cases, where a mesodermatic layer is also formed (*e.g.*, anthozoa), this is subsequently developed from either of the former. No further differentiation of the cells takes place, because the undeveloped adhesive properties of the protoplasm allow the new cells to be arranged in such a way that no other conditions of existence can arise. Each new cell discharges its liquid secretions, and no necessity for the formation of a perigastrium arises.

But all this changes so soon as the adhesivity and solidity of the protoplasm become greater, and its faculty of differentiation, *i.e.*, its sensibility towards external influences, increases. The first important consequence is that the embryonal cells which are situated between the exodermatic and entodermatic layers are firmly encased, and have no longer the same development as the outward and inward surface cells of the body. Hence a mesodermatic layer, of different origin than the one above described, makes its

appearance. Now we have to remember that it is a general property of animal protoplasm to produce liquid secretions. The central cells, which are neither in contact with the outer surface of the body, nor with the cavity of the intestine, cannot directly discharge these secretions, and the result depends exclusively on the greater or less permeability of the surface cells. If this permeability is great, no separation of the different parts of the body will take place ; but in the opposite case a furrow will be formed for the removal of the secretions. The locality of this furrow also depends on physical considerations, viz., it will always occur at the spot where the exosmotic equilibrium between the exodermatic and entodermatic layers takes place. The place of this equilibrium is nearer to the entodermatic than to the exodermatic layer, because the liquid in the cavity of nutrition differs less from the swelling-liquid than from the liquid between the integuments of the egg and the exodermatic layer. Therefore, the portion of the mesodermatic layer which is near to the exodermatic layer (*animal muscularis*) will be larger than that which is connected with the entodermatic layer, in order to produce the intestine.

We will now examine the difference between the two types of coelenterates, viz., the sponges and the sea-nettles. The chief difference of structure is that the cells of the exodermatic layer of the sponges form a coherent stratum of protoplasm, while the exodermatic cells of the sea-nettles are merely in a state of adhesion to one another. Moreover, the entodermatic cells of the sponges are flagellogenous, *i.e.*, they form whip-cells, while those of the sea-nettles are non-flagellogenous. From what I have said, we must come to the conclusion that the protoplasm of the sponges is in a more liquid state than that of the sea-nettles.

As soon as we have reached the stage of the *enterate* animals, the animal kingdom forms *four types*, viz. : the echinoderms, the molluscs, the articulates, and the vertebrates. We must now investigate the characteristic differences of the germ-plasma of these four types. Each is characterised by certain chemical substances, which are either plastic secretions, or materials which are mechanically imbedded in the protoplasm. The echinoderms are characterised by certain *chalky* substances embedded in the protoplasm. The latter is therefore in this case *endocalcigenous.*

The molluscs, on the other hand, form chalky compounds on the surface of their bodies ; their protoplasm is therefore *exocalcigenous*. Thirdly, the vertebrates have the property of producing in the interior of their bodies certain albuminoid substances, of which chondrigen is the most characteristic. We must therefore describe their protoplasm as *chondrigenous*. Finally, the articulates are characterised by the production of chitin, and we therefore speak of the *chitinogenous* disposition of their protoplasm.

It is a characteristic sign of the one-sidedness of the present embryological methods of research, that men like *His* and *Götte*, who have most carefully studied the embryological development of various animals, have completely disregarded the chemical and physical differences of protoplasm.

Moreover, we shall afterwards see that they have disregarded another factor of the highest importance in connection with the differentiation of animals, viz., *the influence of the force of gravitation*.

That the chemical differences of the protoplasm of the different animal types are not hypothetical, but actual, has been conclusively proved by chemical analysis ; and I owe a debt of gratitude to my colleague, *Prof. Dr. O. Schmidt*, who has examined a number of different animals in this respect.

## V.—ON THE ORIGIN OF SPECIES.

(1874.)

THE old biologists, commencing with *Aristoteles*, defined the word species as a mere expression used in logic, in order to connect equal organisms and so separate them from others. *John Ray* was the first who treated the word species as a genetic definition. He described individually identical organisms as belonging to the same species. *Ray's* views are based on the assumption that a species constantly retains its specific properties, and cannot vary in the slightest degree. But in the same publication *Ray* adds the following very important remarks, viz., that this definition of specific invariability, although mostly applicable, is by no means permanent or infallible, because some organisms degenerate ; and even if we assume that only in rare cases are organisms produced which differ from their parental forms, we should by no means under-estimate these important processes. In all such cases we have to do, as experiments prove, with variations from the specific form (*transmutatio specierum*). It is evident from these facts that the scientists who first defined the nature of organic species did not intend to describe it as an invariable factor. It was no less a man than *Linné* who combined with the definition of organic species that theory of invariability which reigned supreme until *Darwin* proved it to be erroneous. *Linné* said : "There are as many organic species as have been originally created ; and these produce, according to the laws of propagation, individuals which are always similar to their parents." If we regard the invariability of species in this light, we find that many animal species have not changed their principal features during a number of long geological periods ; and, still more, we find that within the comparatively short range of human history, most animals (*e.g.*, those known 3000 years ago to the old Egyptians) have not changed in the least. But in striking contrast to such cases of invariability we

have numerous proofs that animal species vary—in many cases to a considerable extent. This fact is chiefly supported by the observation of our domesticated animals and plants, the great variability of which has never been seriously disputed. Moreover, we also know of a number of species in a free state which show great variability. The most important instance of the latter description is that of the mollusc known as *Valvata multiformis*, the great variability of which has been proved by *Hilgendorf*. Further instances are those of *Ammonites subradiatus*, proved to vary by *Waagen*, and the analogous observations made by *Würtenberger* and *Mayer*.* To these cases I might add a considerable number which, after palæontologists had been made aware of the facts, were easily discovered, and to which numerous others will doubtless be added in future. All observations in connection with the question of the variability of species point to the fact, that there are species which in the course of a great many generations have changed their characteristic properties, and others which have not. We therefore arrive at the conclusion that animal species behave very differently as regards the question of variability. Since *Darwin's* discoveries, scientists have been divided on this question into two scientific schools, which I may describe as the *constantian* and the *transmutist* schools. The former maintain that the well-established variability of the domesticated animals is by no means an important feature; that so soon as the forces of nature may act freely, it readjusts itself again; and that there is nothing which goes beyond the scope of individual variability. Moreover, they assert that these cases are by no means numerous, and can be ignored altogether, being merely like oscillations of a pendulum, which always returns in the end to the same invariable position. This is, of course, incorrect, but, on the other hand, I believe that the transmutists have recently fallen into a similar dogmatic mistake. It is well known that numerous species change their characteristic features in the course of time. Starting from this fact, the transmutists assert that other species which are stationary are merely without suitable external conditions to enable them to vary. They say that the invariability of certain species

* Subsequently, in 1884, I have likewise proved the variability of a number of Lias Ammonites.—See Jahresh. Ver. Würt. Naturkunde, 1885.—The Ed.

does not prove anything against the law of variability, and that we may therefore state with emphasis that all animal species are variable.

There are, no doubt, certain kinds of animals which appear invariable in the sense of the constantians, and in their case the old Latin proverb holds good "*Sint ut sunt aut non sint,*" *i.e.*, as soon as certain organisms come under certain new external conditions they simply perish, without being able to produce any new variations. But it is just as evident that other species exist in which a certain degree of variability is possible, as they adapt themselves to the new conditions in such a way that they may be afterwards regarded as new species. The following facts will prove the correctness of this view. First, we have the daily experience before us that individuals of the same kind vary enormously in their physical and psychical properties. For instance, as regards the influence of training, and so on, it is known that there are certain individuals among men, as well as among domesticated animals, which behave very differently. Second, we may often distinguish certain characteristics and peculiarities which induce us to subdivide the species into varieties, or races. When we have to deal with the human species, we have no difficulty in distinguishing between the so-called civilized races and their ancestors (Arians, Semites, &c., &c.), which illustrate the principle of variability, as compared with the invariable and savage races (such as the Indians, Melanesians, Bushmen, &c., &c.) Our next step is to investigate the behaviour of the species themselves. Observations of our domesticated animals prove that the *morphological formative energy* is different in many cases. We must, no doubt, be very careful in all conclusions which we draw in this respect, as individual differences are often to a large extent due to the fact that when man domesticated these animals he had either only one object or several different objects in view. We have thus in many cases to deal with artificial experiments of breeding, in consequence of which different kinds of variabilities may be observed, so soon as we have one or the other of the different domesticating influences before us. But quite apart from these differences, we are forced to admit that a species can only be subdivided into races when we have to deal with pliant and flexible forms. We can easily

observe the causes of these differences, and are therefore able to *check* their effects. On the other hand, it lies in the nature of artificial domestication that variations are rarely reproduced ; and so long as the species in question is not subject to any special changes, the course of the functions of the living substance is not disturbed.

For instance, nobody would have hit upon the idea of producing fowls without tails, until an abnormal specimen showed the possibility of producing such a variation. Moreover, we are quite unable to understand the peacock-pigeon variety, unless we assume that at a certain time an individual showed this peculiar characteristic. The variability of wild animals differs greatly as regards *quale* and *quantum*. On the one side there are species in which it is exceedingly difficult to find an individual which differs from the rest, while on the other we have plenty of animal species which consist throughout of more or less varying forms ; in fact, some of them differ so greatly that we can hardly tell where to draw the line between two species. If we investigate these differences, we usually find that in the genera which contain a great number of species many of the latter are invariable, but that always some of them are variable.

We must add to these facts the experiences gained in zoological gardens in keeping and acclimatising wild animals. I have established that a number of the differences in connection therewith are due to external circumstances. But, whatever may be the reason of constitutional peculiarities, the fact remains that animal species of the same kind and of the same country behave very differently as regards acclimatisation and captivity. Some of them are quite capable of retaining their original vital energy, and these, as a rule, propagate their species in our zoological gardens without any difficulty ; while others can be kept, but do not propagate ; and a third group consists of those which, in spite of all care, cannot be acclimatised in captivity. Also as regards *taming*, the variability of different closely related species of wild animals is very great. It is sufficient to mention some well-known facts : The taming of the lion is a comparatively easy matter, while its nearest relative, the tiger, is exceedingly difficult to tame. The same is the case with the marten, as compared with the weasel ; with marmot and hamster, and so on. Another interesting example,

belonging to quite a different animal type, is afforded by two very similar kinds of silkworms, which I have closely studied during the last few years, viz. :—*Antherea yama-mai* and *Antherea mylitta*, (variety *Pernyi*). Both belong to the same genus, and feed on oak leaves. The caterpillars of the first named species emerge from the egg as early as the first part of April, when no oak leaves have formed in our climate. This species has, so far, resisted attempts to postpone the time of leaving the egg ; all my efforts in using lower temperatures for the purpose have been futile, and the caterpillars will rather perish than remain longer in the eggs. Its near relative behaves quite differently. Within four years I have succeeded in completely changing its process of development. In its free state it is bivoltine, *i.e.*, it produces two generations in the course of one year. But I have, with very little trouble, transformed it into an univoltine species, and have also completely altered the time of leaving the eggs. Under ordinary circumstances this takes place in May, June and July, but I had no difficulty in delaying it till July, August and September, *i.e.* for fully two months. The most important point in this respect appears to me to be the following : If all species varied in the manner indicated by the transmutists, the animal kingdom would show a far greater number of different species than it actually does. Let us assume for a moment that it takes about 100,000 years (which I consider a fairly sufficient time) to produce a new species. Then we have, at the end of this period, two species originating from one, and after a million years $2^{10}$, equal to 1024, or, in round figures, 1000 species; after two million years, $1000 \times 1000 = 1{,}000{,}000$ species; and after four million years, one billion of different species. As regards these long periods of time, we must remember that geologists deal with still greater figures in computing the time of development of the animal kingdom. And yet our computation is already enormously beyond the number of existing animal species, which are estimated at about 200,000.

Secondly, the whole arrangement of the animal kingdom would be totally different if all species had been at the same time, and in the same way, equally productive. In this case every genus would have almost the same number of species, every family about the same number of genera, every order about the same number of

families, and so on. But the fact that the genera differ greatly in this respect, viz., that there are some which contain only a few species, and others which contain many thousands, is an absolute proof of the correctness of my view as explained above, that there are *flexible*, as well as *rigid*, species in the animal kingdom. This view is completely confirmed by the researches of palæontology. Where we find groups with only a few and constant species, we often discover that a great variety of them have existed in former geological periods. Cephalopodes, crinoides, and the ganoid fishes are good examples in this respect. These are the species whose genera have, so to speak, been decimated in the course of thousands of years. Most of them have died and disappeared, because they had lost their formative and flexible constitutional energy: "*Sint ut sunt aut non sint.*" The fact that such an enormous number of fossil species are no longer in existence may be due to one of two reasons. First, a part of them may have disappeared because they died without leaving descendants; and second, the disappearance may not be due to actual destruction, but to all their descendants having changed to such a degree as to form a new species. The first group mentioned comprises the rigid forms, which we properly describe as *invariable species*; while the second group comprises all plastic animals, by means of which the various faunas, of the different geological periods are connected with one another. The transmutists have too much neglected the question of the destruction of species. If it were correct that all animal species have the faculty of adapting themselves to new conditions of life, the destruction and disappearance of species would be a very rare occurrence, unless we go back to the old theory of periodic catastrophes, in which most of the animals of the different geological periods are supposed to have perished. Palæontologists like *Barrande* are correct in asserting that, according to the theory of transmutation, the number of species of a certain group of animals would be steadily increasing; while, in reality, the palæontological discoveries show nothing but variations and oscillations in this respect. It is erroneous to assume that in the animal kingdom we have to deal with *general variability*. But as soon as we distinguish between variable and invariable species, the whole problem is

explained in a satisfactory manner. The first question is: In what relation do these two kinds stand to one another? *Weissmann*, in accordance with my own investigations, correctly states that we have to distinguish in every species between two periods of development, viz., one of variability, or, better expressed, plasticity, followed by a second period of implasticity and absolute invariability. As to the duration of these two periods, we may say that the longer a species is kept on the same level, with regard to natural selection and adaptation, the less is its formative energy, and finally a point is reached where adaptation is no longer possible. Thus we arrive at the same conception of animal history, which, long before *Darwin*, was defended by many palæontologists, especially by *Bronn*, who correctly compares the development of the species with that of the individual. In both cases the development consists of three periods, viz., youth, adult age, and senility. The only point in which this comparison must be modified, is, that during the first period after a new species has come into existence, it shows very great plasticity. If the species is subject for a long time to the same external influences, the constitutional properties of the species change in a similar way to those of an individual entering on the adult age. The plasticity is gradually lost, with the result that the species will become extinct sooner or later, when new external influences come into play. But if during the first plastic period a change of the external conditions takes place, the species will adapt itself to the new functions, by producing morphological changes, and these changes will exercise an invigorating influence on the whole development of the species. This observation is based on numerous facts which we notice in single individuals, as well as in whole generations. Functional changes, change of air and climate, &c., in short, all changes of the external conditions of life, may have an invigorating influence. This is plainly seen in the domestication of animals. If the conditions of existence are always the same, *close-breeding* produces deterioration of the species.

On the other hand, members of the same family can, without injury in respect of specific development, propagate the species so soon as a certain morphological difference exists between the individuals.

In order to further understand the fate of a species in the course of many generations, we must consider the following factors :—The injurious consequences of too close relationship, with reference to fertility and constitutional strength, are always noticeable when there is marked constitutional similarity of the parents. An instance of this kind is the tendency to blindness in children when both parents are very short-sighted. This similarity may either be the consequence of blood relationship, or of the influence of equal external conditions extending over a long time. Keeping this in mind, when variable species are compared with invariable ones, we observe that the constitutional strength of the latter becomes less, on account of the great similarity of the individuals; while, with variable species, union between relatives is open to much less objection of this kind. Observations of domesticated animals accord with this theory: Invariable species, as peacocks, pheasants, &c., have much less constitutional strength than pigeons and poultry, and there is a great difference as regards their powers of propagation. The consequence is that invariable species, when weakened by the influences of too close relationship, are much more likely to be destroyed than variable ones. This is in accordance with the further observation that species well known to be variable are at the same time characterised by an exceedingly large number of individuals.

This explains a new feature which has reference to the fate of the species in course of time. If an animal species lives under such unfavourable conditions of propagation that the individuals cannot increase their number, and that consequently their inclination to vary will be gradually reduced, because variations occur very seldom, the species will arrive much earlier at the stage where it is liable to become constant. On the other hand, when the variability and the number of individuals are great, we have to deal with smaller external obstacles. Thus, the alternatives of variability or constancy, of a larger or smaller amount of constitutional strength, of an earlier or later prospect of becoming invariable, all depend in a high degree on the external conditions of existence. But we can go still further. According to the well-known law, that in the course of development every effect becomes in its way a cause, permanent close-breeding produces permanency and equality of the descendants. This refers

not only to their morphological equality, but also to their great similarity with reference to inclinations, customs, and habits.

Let us assume that one of these more or less non-plastic species is subjected to an unfavourable change in the external conditions of life. For example, if the amount of moisture decreases, a species may find that certain parts of a territory cease to be habitable ; or if a climate becomes colder, many animals will be forced to inhabit only the warmer parts of the territories in question. Or new enemies may migrate into a country, and the species may be obliged to retreat to localities which afford more protection. In short, in all cases of this kind the area of territory available for the species becomes smaller, and the number of individuals more limited. Under these conditions the species becomes more and more restricted, and finally the whole territory, which was previously inhabited by a great number of varying individuals of this species, is divided into small separated districts, a circumstance which greatly impedes sexual relations between the members of this species. In this state of things, *close-breeding* makes its influence felt in a much more pronounced degree, the result being that the constitutional strength of the individuals further decreases. In connection herewith is the interesting fact that species consisting only of a small number of individuals can often only be domesticated with difficulty, while the individuals of large species are, as a rule, easily domesticated. Moreover, solitary animals are much less tractable than social animals : *e.g.*, the snipe as compared with the plover. Finally, so-called "monomanial" species are more difficult to deal with than the so-called "universal" species, *e.g.*, among the stilts the yellow wagtail (*Motacilla sulphurea*) is of more precarious health than the ordinary white wagtail (*Motacilla alba*).

Recapitulating my conclusions with reference to the different behaviour of a species in the course of many generations, we find :—

(1) A difference exists between the invariable, rigid species and those species which are more or less plastic, and capable of varying in the course of many generations.

(2) Every species has two phases in the course of its development and existence, the first being the phase of variability or plasticity, and the second that of constancy and non-plasticity. At the end of the latter phase the species is liable to become extinct.

(3) The species is only able to produce new variations and species during the first phase.

(4) Whenever this takes place, changes in the conditions of existence are of great physiological importance, because they raise the standard of constitutional strength, and are therefore favourable to an extended duration of the species.

(5) The same physiological factor makes itself felt when natural selection places no obstacles in the way of changes of this kind.

(6) The phase of invariability of a species is the consequence of all the factors which tend to enhance the equality of the descendants. This leads, as we have seen, to close-breeding, caused by a great equality of the conditions of life, as well as by a limited number of individuals; and close-breeding itself is another reason for all individuals of the species to become more or less equalized.

(7) If such a species is still further limited in the number of individuals, either by unfavourable external influences, or by the splitting-up of its former territory into unconnected districts, close-breeding will necessarily reach a very high degree, and as a consequence the species is doomed to perish sooner or later.

As regards the variability of animal species in connection with external influences, we find, as I have mentioned before, that we have to deal with plastic, as well as with non-plastic, forms. We notice, *e.g.*, that there is a great difference between animals which can easily be fattened and others which it is impossible to fatten. Wild animals show this difference in a much more pronounced way than domesticated animals. We see that many species vary considerably under the influence of plentiful nourishment, while others reject any variation in the quantity of their food, dying if it is not enough, and refusing it if it is too much. As regards the *quality* of food we observe analogous differences. On the one hand we have species which prefer starvation to any change in the quality of their food, while others adapt themselves without difficulty to new conditions in this respect.

For example, every keeper of silk-worms knows that various species feed on different kinds of leaves, the result being a number of variations within the species (*e.g.*, in the case of *Bombyx Caja*). Other species resist any attempt to change their food. Further

noteworthy instances are the following:—When thistle-finches are fed with hemp-seed their feathers become darker; if a horse has an addition of arsenic to its usual food its hair becomes more glossy; and *Holmegreen* has proved that if pigeons are fed with meat they change not only the colour of their feathers, but also their odour. Differences of temperature act in the same way. Many animal species are greatly affected by the slightest difference of temperature, and some of the cold-blooded vertebrates show the influence of different temperatures in a striking way. When the temperature is high they are lively and active, but so soon as it declines they fall into a torpid state. Warm-blooded animals are capable of resisting much greater climatic changes without danger to their vital functions. As regards the morphological differences connected with climatic changes, we observe that there are many species which remain absolutely unaltered under different climatic conditions, while others seem to vary with almost every change of temperature. For instance, my friend *Dr. Beer* succeeded in breeding ordinary green frogs which reached the full size of the tropical species of *Rana esculenta*, by merely keeping them in an atmosphere of tropical temperature. This behaviour under different temperatures finds its physiological explanation in the fact that warm-blooded animals have a heat-regulating, apparatus which is either absent, or incompletely developed, in all cold-blooded animals.

Physiology has established that many animals are also provided with an apparatus regulating their *growth*. I am decidedly of opinion that analogous physiological arrangements exist for the regulation of all similar external influences. The more promptly these regulating arrangements act, the better adapted are the species possessing them to resist injurious external influences. I may add that experience shows these regulating arrangements to be by no means invariable; but they can be developed or improved by individual training and exercise. We therefore arrive at the following conclusions: Firstly, organisms subject to different external influences may differ greatly as regards plasticity and variability. Secondly, we have reason to believe that these differences are due to a greater or less development of certain regulating arrangements of the animal body. Thirdly, it is highly

probable that a direct connection exists between a number of external influences and the development of these regulating arrangements.

I believe that by the explanations given in this chapter the doctrine of the origin of species has been modified, and its solution considerably advanced. First, a number of objections which had been raised against the doctrine of transmutation are now removed. Second, a great many facts which were quite unintelligible, as long as transmutation was supposed to be *always* active, are now explained. Finally, my explanations accord with the large amount of experience and experiments connected with the domestication and breeding of animals.

## VI.—SEXUAL SELECTION.

(1874.)

AMONG the different kinds of natural selection, sexual selection is one of the most important and direct processes of animal life. Whoever has noticed the competition of individuals with regard to it will be aware of this fact. For example, among the singing-birds, the best singer attracts the greatest number of female birds, and the stronger he is, the greater will be the number of competitors whom he defeats. Moreover, all competition in connection with sexual selection influences a large number of individuals, and extends over a considerable time ; as, even after many of the successful individuals have long given up the competition, the struggle among the inferior individuals still goes on. Those who are excluded from the function of propagation, and those who succeed only at the end of the struggle, are always the weakest ; and we can therefore understand the great influence of sexual selection, not only upon individual propagation, but also on the general development of the animal kingdom. As regards the different parts which each sex plays in sexual selection, it is erroneous to assume that only the male is active ; on the contrary, both sexes are active, and we have therefore to consider two processes which are essentially different. The first of these processes is the struggle between the male competitors, in which the female animal is a passive spectator. Sexual competitions of this kind are exemplified by the fighting of stags, of cocks, &c. These competitive contests have led to the male sex being provided with special weapons, *e.g.*, the stag has his horns, the cock his spurs, &c., &c. Additional features are increased strength and size of the body, and eagerness for combat ; and these characteristics include a series of physiological and morphological differences, *e.g.*, the different taste of the flesh of the male animals in question, the difference of the organs of voice between the sexes, &c., &c. As in this competition

the female animals are passive, it is plain that their development is not thereby influenced ; consequently all secondary characteristics of this kind are absent from the female sex. In the second process, selection is exercised by the females, and the secondary sexual characteristics, which are the result of this female selection, are exclusively, or at least principally, found in the male sex. If we examine the behaviour of the female animal before copulation, we find the following remarkable differences. In certain animals the female shows no desire for copulation, and makes no advances to the male ; *e.g.*, among many amphybia and insects the male partner has simply to wait until the female is willing. Other animals show the still more remarkable characteristic that the female resists the attempt made by the male, so that the male animal is obliged to use force in order to attain its purpose. In both these cases we find that certain organs for catching and holding the unwilling female animal are developed. In a third case, the female shows an active desire for copulation. This is the case with many animals, and then no such organs are necessary, nor are they found among these animals. Here, the decision whether copulation shall take place rests entirely with the females. Experience amply proves this, *e.g.*, I have never noticed that in the group of monogamic birds, a female was rejected by a male bird, while the converse is very frequent. We may say that the male animals, as a rule, excite the female *sensually*. I emphasize the word sensually, and do not say sexually, because it is first a sensual excitement, and only afterwards a sexual one, the latter being the physiological result of the former.

All senses are active in sexual selection, but the part which they play varies greatly, as some animals become sexually excited by one sense and others by another. It is evident that the difference is in connection with the relative development of the senses. Thus it is in accordance with the high development of the eyes of the birds that these animals are principally guided by everything connected with light and colour. Whoever has observed day-birds knows how much they are influenced by light. It is therefore quite intelligible that, so far as birds are concerned, bright colours are in close connection with sexual selection. As regards the sense of hearing, I need only point out the part which music (more or less harmonious)

plays in the erotic excitement of the singing-birds and of various other groups of animals. As regards the sense of smell, it seems, at first sight, strange that we do not more frequently notice the development of secondary sexual characters, as the sense of smell is in many cases in direct connection with sexual excitement. All that we know in this respect is that the males of numerous mammals have, at the time of rutting, a much stronger exhalation than the female animals (stag, chamois, &c.), and that a few mammals, *e.g.*, the beaver, are provided with odour-glands.

*Darwin's* view that everywhere in the animal kingdom the male animals seek the females is quite correct ; and in investigating the question of the development of secondary sexual differences, we must first ask, by what means is a male animal guided in finding its female partner ? So far as the mammals are concerned, the answer is simple, viz., the male animal is guided by the sense of smell. In the sexual relations of human beings the sense of smell plays a subordinate part, as, under the influence of social development, this sense has ceased to guide man as it probably used to do in primæval times. Man is principally guided by the eye, in accordance with the important part which this organ plays in the question of self-preservation. If a male mammal seeks its female partner, it is guided by the specific odour of the latter ; and, therefore, we might expect that odour-glands or similar organs are developed as secondary sexual organs. But this is not the case, evidently because a less pronounced, and decidedly specific, exhalation is preferred. No doubt *Darwin* has attached too much importance to the factor of individual beauty. Although a certain degree of psychological development may be a condition of sexual selection in many cases, we must not forget that the lower animals, and their means of attracting the other sex, cannot be affected by psychological development ; and that many circumstances must be regarded as stimulating influences, acting in the direction of sexual selection.

Moreover, I should like to point out a circumstance which has been greatly under-estimated and neglected, viz., that sexual selection *alone* does not explain many secondary sexual differences.

The struggle for self-preservation plays an important part in the development of secondary sexual differences which might be

of great disadvantage to the female individuals of the species. For example, bright colours would be distinctly dangerous to female birds during the period of hatching, as they would attract the attention of their enemies. But in the case of those female birds which, during the period of hatching, cannot easily be seen, there is no reason why the bright colours produced by sexual selection in the male sex should not be likewise transferred to the female ; and that this is the case is confirmed by numerous observations. For example, birds breeding in caves show, as a rule, no great difference between the two sexes, and most of them are characterised by a variety of colours, *e.g.*, kingfishers, parrots, pigeons, &c.

For all these reasons I am inclined to attribute considerably more importance to sexual selection than *Darwin* does ; while, on the other hand, I am of opinion that we have to limit its importance in cases in which we observe secondary sexual differences. For, in sexual selection, I can only recognise a principle which is insufficient in itself to explain these facts, and which must therefore be supported by natural selection, as otherwise the characters in question would also be transferred to the female sex. In favour of this assertion is the observation that the females of bright-coloured birds are always less intensively coloured than the males, this difference being due to the circumstance that these colours appeared earlier in the male sex than in the female. The existence of rudimentary mammary glands in male mammals is a further proof that organs which are of importance to one sex may easily be transferred to the other, if no functional obstacles prevent their adoption. The assertion which has been made by various authors, that only female birds are attracted by bright colours, and that male birds are indifferent thereto, is incorrect, as both sexes plainly show the same inclination in this respect. But brilliant colours are, as we have seen, a great danger for many female birds during the period of hatching ; and the inclination of the male birds for bright colours can only exercise its influence on the female birds when this danger is removed, as in the case of cave-breeding birds. The same argument holds good with regard to singing. What would be the fate of a female bird and its young, if the former tried to sing while engaged in hatching ? A case by which *Darwin* was considerably puzzled, viz., that of bright-coloured male butterflies, is easily explained in a

corresponding manner. After the act of fertilization, the life of the males is without any value for the propagation of the species, while the females have to attend to the important and lengthy function of depositing the eggs. Brilliant colours which might attract their enemies would therefore be disadvantageous to the propagation of the species. This, again, throws further light on the important problem of the origin of the secondary sexual characters of female animals. Natural selection prevents the transfer of many characteristic features of the male animals to the other sex, as these features would be a source of great danger to the females. But many observations show that the inclination to transfer these properties is often noticeable. For example, we occasionally find that pheasant hens are adorned with some of the characteristic feathers of the male sex. The consequence of the influence of natural selection is that, as a rule, the secondary sexual features of the females are of a negative character. As regards the application of the principles of sexual selection to the human species, *Darwin* has been very cautious and reserved, and has consequently created for himself some unnecessary difficulties. In explaining the secondary sexual features, he only takes into account the direct influence of sexual selection. But, as I have now explained, this factor, alone, produces exactly the opposite result, viz., the equality of the individuals of both sexes.

*Darwin's* second difficulty is, that he considers selection to be principally exercised by one sex only, an assumption which I regard as neither theoretically necessary nor actually correct. The third difficulty is, that he regards the human species too much from a zoological point of view. But man differs in this respect enormously from all animal species, on account of the very great variety of races, nations, tribes, languages, occupations, &c., &c. The superiority which man has obtained by his much greater corporeal and intellectual development, has procured for him a freedom of action which far surpasses everything else to be found in the animal kingdom. For this reason human marriage has ceased to be a specific feature, and has transformed itself into a national or religious feature; *i.e.*, it is no longer a somatic, but a social, institution. I must confess that among all subject-matters of *Darwin's* investigations, that dealing with the descent of man has satisfied me least, and the same may be said of *Haeckel's*

researches in this line. Both scientists have tried to solve the mystery almost exclusively by means of zoological reasoning, with the assistance of natural selection; and they neglect the most important factor, viz., the morphogenetic properties. With these I have dealt in my essay on the development of infants, to which I refer the reader.* Natural, as well as sexual, selection has doubtless played a highly important part in developing the general characteristics of man, *but by no means everything is due to them.* I will not here enter into anthropological details, with which I shall deal in Part II. of this volume; but I must refer to one important point. *Wallace* has correctly remarked that human macrocephalia must have been in existence prior to the development of human intelligence; and that it cannot therefore be a product of natural selection, because a largely developed brain can only be useful when it produces more active energy. I mention this case because it is an excellent example of consecutive and accompanying features. The main factor in the development of the human body is the adoption of the upright gait, and the corresponding differentiation of the extremities thereby produced. The enlargements of the pelvis and of the uterus, and, in connection therewith, the characteristic position of the embryo in the latter, with its head downwards, are accompanying features, or rather, quite unintentional effects, of the upright stature, and are direct consequences of the force of gravitation. Through this position of the embryo the human brain is largely developed, without the influence of any use or habit, or of natural selection. The chief anatomical characteristics of man are therefore the direct result of the influence of the force of gravitation, while the part of natural selection is only that of an assisting force.

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* See chapter XXVII.

# VII.—DARWIN'S PANGENESIS AND THE DIFFERENT KINDS OF ANIMAL CELLS.

(1875.)

WE will now investigate the general causes whose influence is noticeable in every organic development. This is an important question, as the great progress of science, due to *Darwin's* discoveries, has led to a danger of taking one-sided views in various respects. If we would follow the course of individual development from the egg to the grown-up organism, we must consider three different factors, viz. :

1. The differentiation of the tissues, whereby the embryonal cells, which at the beginning are all identical, gradually change their qualities, and become different from one another ;

2. The circumstance that the development from generation to generation invariably takes place in exactly the same way ;

3. The observation that the development does not always lead to highly organised organic bodies, but that there are many different degrees of development.

The causes of these factors must be looked for in two different directions, viz., they are either *external* or *internal* forms of development. The internal causes are in direct connection with the substance of the germ and its properties, both depending, of course, on the respective qualities of the parental animals. Little is known, at present, of the ultimate causes of these internal forms of development, which we generally define as inheritance.*

As regards the external causes, we have to consider that animal germs can only develop by the constant change of substance and force, in connection with the surrounding media. Further, that the germs are under the permanent influence of the most important

* Compare chapter IX.

external agencies, such as force of gravitation, affinity, &c., as well as subject to certain specific external conditions, produced by space, substance, and motion. At a time when morphogenesis was merely treated symptomatically, *inheritance* was regarded as the only formative force in the animal kingdom, while the part which the external causes play was described as conservative, *i.e.*, they were looked upon as not being able to change, in any way, the course and object of development.

But *Geoffroy St. Hilaire* had already emphasized the influence of the external causes; and numerous observations have recently been critically compared and analysed, which prove that these causes have a *direct formative influence* on organic development.

Further, it is one of *Darwin's* greatest discoveries to have shown the enormous *indirect influence* which these external causes exercise on all organic development, by means of *adaptation* and *natural selection*. *Darwin* has, moreover, fully explained the effect of inheritance on the formal course of individual development. The result of these important discoveries is that we have been enabled to understand the significance of the law, that the development of every individual is a short repetition of the history of its species.

Thus the advance in knowledge is enormous, but a danger lies in the fact that the causal importance of many explanations has been over-estimated.

I shall therefore criticize various inaccuracies in this respect. The first of them is *Darwin's theory of pangenesis*. The object of this theory is to render the problem of inheritance more intelligible. According to it, the egg-cells and the sperma-cells must not be regarded as ordinary cells; *Darwin* is of opinion that they represent, so to speak, a quintessence of all organs of the parental animals. *Darwin* imagines that, in order to obtain these germ substances, every organ, and every group of organs, produces minute germs, all of which have the capacity to multiply, and to build up in the embryo the identical organ, or group of organs, from which these minute germs have originated. He thus assumes that the fertilized egg consists of a great number of specific germs of all the organs of the animal body (*e.g.*, separate germs for feet, hands, liver, stomach, intestines, brain, blood, &c.).

According to this theory, we have in the fertilized egg a complete micro-organism of the animal before us. But against this view a number of serious objections must be raised :

1. It is quite unintelligible by what means all these minute germs are brought together, and distributed to each of the many millions of spermatozoides, as well as to every single egg-cell.

2. It likewise remains unknown how confusion as regards quality and quantity can be avoided, and how every single minute germ finds its correct place. For example, an eye germ might, by mistake, easily occupy the place where the liver or the heart should be, and so on.

3. The question of inheritance has received no assistance whatever from this theory, because the correct arrangement of the minute germs is just as complicated, and by no means more intelligible than the actual fact that the whole animal is developed from the egg.

One of the most important causes in the individual development of animals, is, as we have seen, the differentiation of the tissues by which identical embryonal cells develop themselves into all sorts of totally different organs. According to the theory of pangenesis, different tissue cells are *not* the descendants of equal embryonal cells, but the descendants of those minute germs which are supposed to have been deposited in the fertilized egg. Such an assumption completely excludes the possibility of investigating the causes of the differentiation of the tissues. But the most superficial observation shows that *the conditions of existence* of the germ, and of the parts of the germ, exercise a great influence on the differentiation of the tissues.

The most striking proof in this respect are the so-called white blood corpuscles. It is well known that, even after the animal has grown up, these white corpuscles are capable of transforming themselves into all sorts of different tissue cells. Moreover, it has been proved that these various transformations of the white blood corpuscles only take place when the latter come under the same conditions of existence as the tissue cells in question. Therefore, this kind of animal cell can have no inherited predestination whatever, as the cells are capable of being transformed into all sorts of different tissues.

The transmutation of the equal embryonal cells into different sorts of tissue cells, and the transformation of the white blood corpuscles, are analogous occurrences, which in all probability are due to similar causes. In the case of the white corpuscles, we know that these causes depend on the external conditions of existence, and not on any inherited properties. Thus the differentiation of the embryonal cells is not likely to be the consequence of an inherited quality, as is assumed by the theory of pangenesis, but is in all probability a consequence of the external conditions of existence. It is interesting to examine more closely the above-mentioned physiological similarity between the embryonal cells and the white blood corpuscles. We find that in two very important respects the latter are nothing but a kind of modified embryonal cells, first, on account of their capability to transform themselves, and, second, because of their tendency to multiply enormously. The embryonal cells prepare the material for the different tissues of the body; and, quite analogously, the white blood corpuscles of the grown-up animal furnish the body with a plastic material for "repairs," which is a necessary item in the structure of the body, as the cells of the latter are being constantly worn out by the daily functions of life. Of all cells of the animal body, the blood-cells are primarily liable to be worn out, and it is therefore evident that they require the largest amount of this "repairing" material. Moreover, when a part of the body is injured, the white blood corpuscles form the material for the tissue of the scar. It has not been proved yet whether they are of importance in the *reproduction** of parts of the body which have been completely lost, but it is very probable that this is the case. I should like to draw the attention of those engaged on this subject to the point.

But it must not be forgotten that there is one great difference between the embryonal cells and the white blood corpuscles, viz., that the latter have a much greater mobility than the former. The white corpuscles are migratory cells, and they not only drift, by means of the lymphatic juices, from one place to another, but they also engage in active motion by means of their pseudo-podia, and thus force their way even through certain tissues.

* This occurrence is met with in various groups of animals.

We have now ascertained that every animal body contains three different classes of cells, viz.:

1. *Finished tissue-cells*, which are incapable of any progressive transformation, and are capable, probably only to a small extent, of multiplication by self-division (muscle-. nerve-, horny-cells, red blood corpuscles, &c.);

2. *Unfinished embryonal-cells*, capable of transformation, and in a large degree of multiplication (white blood corpuscles);

3. *Sexual-cells* (egg-cells and sperma-cells), which, after the act of fertilization, obtain the same properties as the cells of class 2. While the cells of class 1 form the structure of the animal body, the cells of class 2 form the material for repairs, and have the function of conserving the individual. Finally, the cells of class 3 serve to propagate the species.

The following relation exists between these three different classes of cells: The cells of class 3 are developed by fertilization into cells of class 2, and these again are differentiated into cells of class 1.

## VIII.—ON THE PHYSIOLOGICAL IMPORTANCE OF SAVOROUS AND ODOROUS MATTERS.

### (MATTERS WHICH CAN BE TASTED AND SMELLED.)

### (1876.)

BEFORE *Darwin's* discoveries, scientific zoology principally dealt with questions concerning the form and appearance of animals. But as soon as *Darwin* came to the front, all questions referring to the origin and development of animals became of primary importance, and it can now be regarded as an absolute fact that *Darwin's* law of the "natural selection" of animals is the first regulating principle of the organic cosmos. The most important question of the organic world, viz., the problem of descent, was successfully attacked by *Darwin* and his disciples, and the numerous investigations connected therewith have made the last epoch one of the most interesting in the whole history of science.

But a critical examination of the results shows that we have not arrived at the goal which seemed to many to be within easy reach. The result of the Darwinian epoch is the fact—which we now know for certain—that the ultimate goal of organic science lies in the direction of the theory of descent, and in no other.

But when I studied Professor *Haeckel's* well-known essay on the Perigenesis of the Plastidula, I became convinced that this goal cannot possibly be reached by the present biological and morphological methods of research, because neither these methods, nor the most energetic philosophical efforts, can remove the unsurmountable difficulty called *inheritance*. The fact is, we have arrived at the end of our science and philosophy.

Recognising this, it is my object in the present chapter to find a new path into the unknown country, and to try whether the latter cannot be opened up by different means than those hitherto employed.

There is no doubt that the hereditivity of all the characteristic features of an animal species is chiefly due to the chemical and physical properties of its germ-plasma, and only to a small extent to the conditions of development. I have previously shown* that the amount of water in the protoplasm, and the degree of adhesivity and permeability connected therewith, is one of the principal actors which must play an important *physical* part in the process of inheritance. But in this chapter I shall deal with the *chemical* side of the question, discussing some of the chemical properties of various kinds of germ-plasma in connection with inheritance.

As regards chemical questions, zoologists are, as a rule, very badly off. In the handbooks of zoo-chemistry we find a mere handful of substances, which, compared with the many thousands of species of animals, might lead us to the conclusion that the zoo-chemical line of investigation is practically hopeless. But this is not the case, as fortunately we are in possession of two very delicate chemical senses, viz., those of smell and taste, and these may enable us to investigate biological problems which have until now been disregarded altogether.

My starting point is that every animal species has its specific odour. Even an inexperienced person can distinguish by smell a horse from an ox, a dog from a cat, a crow from a pigeon, and a snake from a lizard.

Moreover, we know by experience that the difference in taste of the flesh of various species of animals which we breed for food purposes is specific and pronounced. Not only every animal species, but also every race, variety, and, in all probability, even every individual, has its specific odour and taste. As regards the individual, our own grossly neglected chemical senses cannot be depended upon to guide us ; but we all know that dogs, with their highly developed sense of smell, are capable of distinguishing their masters from other persons by the sense of smell. Many observations on bees, ants, birds, dogs, and other animals prove the same thing ; and we can safely conclude that individual chemical differences are not merely a privilege of man, but are, in all probability, general throughout the animal kingdom.

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* See chapter III.

The chemical difference between varieties and races is much more easily distinguished. As regards the pronounced differences in this respect between the various human races, I need only refer to Professor *Andree's* highly interesting investigations on "The Odours of Nations;" and observations of all species domesticated by man confirm the above fact.

We must now try to find the origin of these specific savorous and odorous matters. Our zoo-chemical handbooks state that the blood of every animal species, when mixed with sulphuric acid, produces exactly the same odour which characterises the excrements of the species in question. Secondly, the specific odour of an animal attaches to all its superficial coverings: skin, hair, wool, feathers, &c., &c. It is plain, from what I have said, that this specific odorous matter cannot be of accidental, or *exogenous* origin, but that it must be a product of the living substance of the animal, *i.e.*, that it is of *endogenous* nature, a fact which is supported by the evidence of our sense of taste.

Of course, the quality of food on which an animal lives is not without influence on these specific odorous and savorous matters, but observation shows that it does not change their *specific* nature.

So far we have only dealt with grown-up animals; but the chemical composition of the germ-plasma is of the utmost importance in the question of inheritance. This part of the subject is much more difficult than any other, as the minute eggs of mammals, insects, &c., &c., cannot possibly be subjected to investigation by means of our chemical senses. Fortunately, the much larger eggs of many birds, reptiles, amphibia, and fishes afford a valuable opportunity in this respect.

As regards the birds, the eggs of every species are distinctly different. Everyone can distinguish by taste the eggs of the hen, duck, goose, plover, &c. From my own experience, as director of the Zoological Gardens at Vienna, I know that many other birds which I have examined (casuary, turkey, peacock, guinea-fowl, pheasant, Californian quail, &c., &c.,) have specifically different eggs. The investigations on the eggs of reptiles, amphibia, and fishes are at the present time incomplete in many respects, but all that we know about them completely confirms what I have so far stated.

For these reasons I have come to the conclusion, that *the substances which produce these specific odours and tastes have not been acquired by the animal during its embryological development, but that they form an important constituent of the germ-plasma itself.* They may therefore help to solve the great mystery of inheritance.

## IX.—INHERITANCE.

(1877.)

IN two of my recent publications I have discussed the question of inheritance,* and it is now my object to further investigate this important matter. The fundamental principle of inheritance is in the closest connection with the specific properties of the germ-plasma. During the embryonal development of animals the germ-plasma is divided into two groups, viz. :—

1. The ontogenetical group, which builds up the body of the animal.

2. The phylogenetical group, which remains unaltered and reserved until its physiological action commences, when the grown-up animal propagates the species. This reserving of the phylogenetical material may appropriately be called *the continuity of the germ-plasma*. Moreover, the ontogenetical portion of the germ-plasma also retains its specific properties during the periods of growth and adaptation.

Now, the most interesting process of the ontogenetical side of inheritance is the function described by all physiological authors as *assimilation*. So far, this function has neither been properly analysed nor has its great importance in connection with the problem of inheritance been sufficiently recognised.

The primary question is : Why is the flesh of a bird which feeds exclusively upon fish not converted into fish-plasma, or that of a fish which eats worms into worm-plasma, or that of a protist which devours diatoms into diatom-plasma ? The only possible answer to this is, that the assimilation acts upon the *specific portion of the food*, and we have no indication whatever that the salts and carbo-hydrates of the food are in any way connected with the process of assimilation.†

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* See chapters III. and VIII.

† That this is correct, and that the protoplasm is at the bottom of the assimilation problem, has quite recently been fully confirmed by the investigations of *Loew*, *Warington*, *Thiselton-Dyer*, *Meldola*, and others (see, for example, Brit. Assoc. Report 1895).—The Ed.

In my previous publications I was obliged to leave the question open, as to what portion of the protoplasm produces the specific odorous and savorous matters, which are, as we have seen, in such close connection with the question of inheritance. But comparing what we have learned about assimilation with the well-known fact that the albuminates, when treated with acids and alkalis, produce the specific odorous matter of the excrements of the particular species, I have come to the conclusion that the *albuminates* form that portion of the animal protoplasm which produces the above-mentioned specific odorous and savorous matters. Hence it follows that the albuminates of different animal species cannot be equal. They probably consist of a nucleus, which is the same in all albuminates, and with this nucleus are connected certain atomic groups, producing, when the albumin molecule becomes decomposed, the specific odorous and savorous matters, for which other atomic groups, similar, but by no means identical, may be substituted, *and this is assimilation.*

Consequently the whole process of assimilation takes place as follows :—The albuminates lose their specific properties, their molecules being decomposed into two atomic groups, one of which is the well-known *albumin peptone*, while the other consists of those substances which we have described as specific odorous and savorous matters. These last-named substances leave the body with the excrements, &c., while the peptone comes into contact with the living protoplasm, and there meets the specific odorous and savorous matters of the animal itself. With these it forms again a compound, giving off water, and in this way the specific albumin of the animal which has taken the food is produced, *i.e.*, *the assimilation is complete.*

If my views on digestion and assimilation are correct, then the ontogenetical part of inheritance is explained by the statement that the albuminates of other animals are not absorbed as such by the protoplasm of the animal which feeds upon them, but that they first lose their specific value, and are only afterwards assimilated. Moreover, the albuminate of an animal which feeds upon various other albuminates retains its specific properties, in spite of the changes which doubtless occur during the embryonal development, in the course of which many different substances, such as globulin, fibrin, haemoglobin, &c., &c., are formed.

This view gives us a definite explanation of the remarkable properties of organic albuminates, and explains the part which they play, not only in the process of inheritance, but also in that of ontogenetic adaptation, viz., they preserve certain atomic groups with extraordinary tenacity, while they easily exchange others.

Furthermore, if our fundamental view about the specific properties of the albumin molecule is admitted to be correct, we arrive at another important conclusion, viz., that transmutation is a process similar to assimilation. If we identify, as *Darwin* does, transmutation and adaptation, we must distinguish between ontogenetical and phylogenetical adaptation. It is evident that, in order to fully understand transmutation in connection with inheritance, we must be able to explain all molecular processes referring to digestion and inheritance.

I have previously explained that the tenacity of the ontogenetical part of inheritance is based on the fact that a foreign albuminate cannot form a compound with the protoplasm in question without being peptonised. Hence two questions arise:—

1. Why cannot such a compound be formed without previous decomposition? 2. By what process is it peptonised?

*Traube's* brilliant experiments on the artificial formation of cells supply the answer to the first question, and they also explain the remarkable predominating influence which the albuminates exercise over all other organic compounds. *Traube* has shown that a substance capable of forming a membrane cannot diffuse through its own membrane, even if the substance be in solution. He explains this as follows: The molecules forming a membrane are arranged in such a manner that the interstices between them are smaller than the molecules themselves. The predominating influence of the albuminates among all other organic compounds which form membranes is due to the fact *that the albuminates have the largest molecules.* Therefore, albumin membranes may allow endosmotic diffusion to all other organic compounds which are soluble in the surrounding medium, and which do not destroy the albumin molecules. *The sole exception are the albumin compounds themselves.* Thus we have not only the predominating influence of large molecules over small ones, but also the physical impossibility that a substance, capable of forming membranes, can feed upon itself (*impossibility of autophagy*).

## X.—THE ANIMAL SOUL.

(1878.)

BY the physical investigations of *Helmholtz*, *Du Bois-Reymond*, *Pflüger* and others, and by the chemical experiments of *J. Ranke*, we have become acquainted with the causes of the organic forces in the animal kingdom, and I myself have recently proved that the vital forces are ponderable quantities.* Therefore, the general conditions of animal life are now fully explained. But this is by no means the case with the *specific* conditions of animal life. For example :—We know the relation which exists between sensibility and organic motions, but we do not know why the same stimuli produce specifically different effects on different species of animals. In short, we know the general conditions of animal life, but we do not know their specific methods. For example : We know why an animal feeds, but we do not know why it feeds upon a well-defined group of substances, and why it refuses all others.

In other words : we know the mechanical part of the forces of the living body, but the reason why these forces always act in a fixed and well-determined direction is entirely unknown to us. In short : we know the locomotive and its construction, but the engine-driver is unknown to us. We have only one name for this driver of the organic engine, viz., *the animal soul.*

*What is the animal soul?* This important question must be dealt with much more seriously than has hitherto been the case, for it is the point where all branches of zoology meet. *In fact, this question is the fundamental problem of organic life.*

Is is well known that *Haeckel* has discussed the subject, and has come to the conclusion that not only every animal, as an individual, has a soul, but also that every egg, every cell, and finally every protoplasmatic element has a soul, which *Haeckel* accordingly

* Seuchenfestigkeit und Constitutionskraft, 1878; compare chapter XXI.

terms *plastidula-soul*. He describes this soul as a sort of rhythmic motion. But we cannot rest satisfied with this explanation, as *Haeckel* neither tells us anything about the nature of the moving agent, nor about the specific character of the motion. Every protoplasmatic motion is life, but we know that a kind of *latent* life exists (*e.g.*, in many eggs) during which we observe no motion whatever. If the animal soul is merely an abstract motion, where is it during this period? And if we suppose it to be temporarily absent, whence does it afterwards come?

Moreover, in physics and chemistry, it is impossible to speak of motion without matter, and the same holds good for zoology; it is therefore impossible to define the animal soul as a peculiar motion.

What we want to discover is *the substance of the animal soul*, and I quite agree with *Haeckel*, that the soul must be present in every egg and cell, and finally in every piece of protoplasm which *Haeckel* calls plastidula; in fact, *the animal soul must be an essential constituent of the protoplasm. I believe that I have solved the problem of the animal soul*, *as I am able to define this constituent of the protoplasm.* I know the far-reaching importance of this statement, and I also know that the opposition will be even greater and more obstinate than at the time when the theory of descent made its first appearance. But we have arrived at a point where progress is no longer possible without encountering the most determined opposition. Two observations will show us the direction in which we have to search for the solution of our problem.

First, when we study the functions by which the soul of an animal manifests itself, we find that they are always of a *specific* nature. Life is a general organic function, but the functions of the soul are in every respect *specific*. Hence it is evident that the soul itself must be *a specific substance*. This excludes those protoplasmatic constituents which are equally met with in all animals, and only substances of an entirely specific nature have to be considered. I have previously shown that there is only one such group, viz., those substances which contain the specific odorous and savorous matters of an animal, because these substances alone are of a completely specific nature.

Secondly, these specific substances are of the utmost importance for the functions of self-preservation and propagation. The food which every animal species selects depends on its specific smell and taste. No experience whatever is necessary in this respect, and the caterpillar, for example, creeping forth from its egg, recognises with unerring certainty the specific plants which form its food. When the kittens of a cat are shown the image of a dog it makes no impression whatever upon them; but if a living dog be rubbed with the hand, and the hand be brought afterwards into contact with the nose of a kitten, the effect is striking, because the cat smells and instinctively recognises its enemy. Hence it is plain that the animals mentioned are in these cases only guided by their chemical senses. Similar "chemical" facts guide the second of the two most important functions of animal life, viz., that of propagation.

Consequently, there can be no doubt that certain specific volatile substances, which act upon the chemical senses of the animals in a specifically different manner, are active agencies in the processes of self-preservation and propagation, *i.e.*, *these substances represent the animal soul.*

In my opinion, the most important points in connection with these volatile substances are their peculiar specific properties, which we recognise and distinguish by means of the sense of smell. But here we have arrived at the limits of our knowledge. We know what sound and light are, and we know how to distinguish tunes and colours from one another: without exception, they are regular oscillations, differing in number and velocity.

But what is a smell? and what is the physiological cause that we can recognise and distinguish different odours with such surprising accuracy? This is an absolutely unsolved problem. That it is not merely a simple chemical reaction is proved by the fact that the air containing odorous matters *must be in motion* in order to make the smell perceptible to us. This fact, as well as the great volatility of the substances in question, seems to point to motions analogous to those which produce hearing and seeing. But such motions would be of a different kind, and all differences in smelling appear to be *qualitative*, while the differences in hearing and seeing are *quantitative*.

My object in discussing these questions is to substitute for the metaphysical and metachemical speculations on the animal soul something more tangible. I regard the animal soul as a distinct chemical substance, subject to the changes of matter, like all other constituents of the animal body.

In conclusion, I should like to state emphatically that apart from this "soul," another, and intellectually far superior, factor exists, viz., *the spirit*, with which I shall deal in chapter XXIX.

# XI.—THE NOXIOUS EMANATIONS OF THE BODY.

(1878.)

IN another chapter of this volume* I have shown that medical science long ago recognised the great importance of the exhalation of the skin. The older medical schools have properly described it as a *materia peccans*. But so soon as modern physiology found that the substance of the exhalation of the skin is scarcely anything but water, the physio-chemical importance of this function was altogether disregarded. I have now collected much further information which proves that we must go back to the old views, and regard the exhalation of the skin as an important therapeutic factor. Although I am not speaking of a *materia peccans* in the old sense, I am positive that the exhalation of the skin may contain a noxious substance, viz., the emanation which is produced through a chemical decomposition of the albuminates of the body by those emotions which are popularly known as fright, terror, &c. The observation that when an animal is frightened—especially when we have to do with mortal fright and terror—malodorous matter emanates from its body, is an old one. According to my own investigations this malodorous matter is not connected with any *special* secretion of the body, but adheres to all of the secretions. I discovered it in the respiratory and cutaneous exhalation of animals, as well as in the urine. A good example in this respect is the ringed snake, which exhales a very pronounced malodorous matter so soon as it is frightened, while under ordinary circumstances no such odour is noticeable. Physiology has until recently completely ignored the significance of these noxious emanations of the body. They have been regarded as something quite accidental, while there are ample proofs that the development of these substances is due to certain well defined functions of the animal body which have not

* See chapter XXII.

hitherto been investigated. The effect of these noxious emanations on the body may be described as paralysing, or laming. This has long been known, but the general opinion, that we have merely to do with an influence of the cerebral nerve centres on certain local nerve mechanisms, is incorrect. The fact is that we have here, as in many other instances, substances which influence *the whole body*. The physiological explanation of *fatigue*, *e.g.*, is quite analogous. In all such cases we recognise the direct influence of chemical substances which find their way into the liquids of the body and are imbibed by the tissues. Consequently, the action of these chemical matters is independent of the nervous system.

The paralysing influence of these substances on the nervous system, and on the motoric apparatus, is noticeable in that state of the body which is described by *Preyer* as cataplexy, and by *Czermak* as hypnotism. Had these scientists used their sense of smell while making their experiments, it could not have escaped them that, so soon as cataplexy sets in, the body exhales malodorous matter. Of course, the cataplectical state is only reached in extreme cases; and if the effects of fright, &c., are limited to lower degrees, we have only to deal with the production of functional obstacles. But a certain amount of paralysis of the muscles is also distinctly noticeable in these cases. For instance, the voluntary motions become uncertain and without energy; and as regards the involuntary motions, we find that the functions of the respiratory organs of the heart and of the other blood vessels become irregular under the influence of these volatile matters.

It might be said that all these effects are due to changes in the functions of the nervous system, but in such a case it would be very strange that these effects are not localized, and that they act in direct contravention to the laws of isolated conductivity. Moreover, the inaccuracy of this explanation is conclusively proved by the participation of the *vegetative* organs of the body. So soon as the body is affected by fright or terror, the vegetative organs show in an unmistakeable and characteristic manner signs of paralytic secretions:—The skin commences to perspire, and this is by no means the same as the normal perspiration which takes place when the capillary vessels are enlarged and full of blood; on the contrary the

capillary vessels are contracted and almost devoid of blood. Hence, the popular phraseology of "cold sweat," produced by fright, is quite correct. The explanation is that, in spite of the contraction of the capillary vessels, the perspiratory gland-cells become paralyzed under the influence of these noxious matters. The effect on the intestines is similar, viz.: malodorous, watery secretions are produced; and assisted by the peristaltic motions of the intestines, and by the paralysis of the muscles of the anus, the result is not seldom an involuntary discharge of malodorous excrements. This is a fact frequently observed in all classes of the animal kingdom. Further paralytic secretions may take place in the liver and in the urinary organs.

Finally, I must mention the remarkable and well-proved fact that the hair of persons who are exposed to an extreme degree of terror and fright may become white. This can only be due to the bleaching effect of these specific noxious emanations upon the human hair, in the same way as other chemical reagents act, *e.g.*, oil of turpentine, peroxide of hydrogen, &c.

If the emanation of these malodorous matters be prevented, they accumulate within the body, which is then seriously affected by them.

From what I have said it is plain that everything which enhances the functions of exhalation and evaporation has a favourable influence on the general state of the body; and the great scientific importance of the volatile matters with which we have dealt in this chapter becomes evident from the fact that we have here substances which permeate the body, and act upon it, without being under the influence of the nervous system.

# XII.—THE DEVELOPMENT OF THE VERTEBRATE TYPE.

(1875.)

THE vertebrate animals form the most important sub-division of the whole animal kingdom. Not only have they been much more carefully investigated than any other group of animals, but man himself is, from a zoological point of view, the highest developed vertebrate animal. For this reason the development of the vertebrates is especially interesting, because it leads to the explanation of many highly important problems concerning the evolution of man.

Having proved that the hereditivity of an animal type is due to the chemical and physical properties of the germ-plasma, we will now first examine, in connection with the subject before us, the gradual development of the germ-plasma, from the lowest animals up to the highest group, viz., the vertebrates. The fundamental biogenetic law* teaches us that we have to regard animals like the rhizopods as the first ancestors of the vertebrates. Then follow unicellulate animals, and, later, simple multicellulates, like the coelenterates; lastly come the more highly developed enterate animals, which gradually transform themselves into vertebrates, by the formation of a spinal axis consisting of chondrigen. This includes a progressive metamorphosis of the germ-plasma from the indifferential † state of the rhizopods to the differential state of the cell animals; from the mobile state of the unicellulates to the adhesive state of the multicellulates; from the non-lymphagenous state of the coelenterates to the lymphagenous state of the enterate animals; and from the fluido-lymphagenous state of the invertebrate animals to the chondrigenous state of the vertebrates.

* Compare chapter III.

† The explanation of this and the following modifications of protoplasm will be found in chapter IV.

It is evident that this metamorphosis is the result of a natural development, as every higher degree originates from that immediately below it, by means of a simple modifying influence, as explained in chapter IV. If we try to arrive at a general conclusion concerning these different protoplasma modifications, we find that they show a gradual decrease in the proportion of water contained in the protoplasm, *i.e.*, *the density of the germ-plasma gradually increases, corresponding to the higher development of animals.* This has been proved by chemical analysis by *Bezold*, *O. Schmidt*, and others, who have found that the proportion of water in different animal bodies is as follows :—

| | |
|---|---|
| Jelly-fish ... ... ... | 99·8 per cent. |
| Slug-snail ... ... ... | 87·0 „ „ |
| Oyster (without shell)... ... | 84·5 „ „ |
| Frog ... ... ... ... | 80·0 „ „ |
| Mouse ... ... ... ... | 70·8 „ „ |
| Bat ... ... ... ... | 68·6 „ „ |
| Man .. ... ... ... | 58·5 „ „ |

These figures clearly show the progress of the density of the protoplasm.

In the group of the vertebrate animals, the first important morphological progress is that from gristle (cartilage) to bone. Instead of chondrigen, the fundamental substance of gristle, we have now to deal with collagen, the fundamental substance of bone, the latter being an albuminoid substance isomerical to the former. This proves that the collagenous disposition of the protoplasm is a simple modification of the chondrigenous. The history of development clearly shows that chondrigen is produced at a much earlier period than collagen.

The second great advance within the vertebrate group is the appearance of *warm-blooded* animals, *i.e.*, the development of calorigenous protoplasm from the osteogenous plasma modification. There is an unmistakeable causal connection between the first appearance of warm-blooded animals and the development of hair and feathers. This we may explain as follows :—If the average temperature of an animal body is considerably higher than that of the surrounding media, oscillations of these media have a stimulating effect upon the skin of the animal. This leads to a

tendency to form papillary chorian cells, and these afterwards produce hair or feathers, which represent two of the most characteristic features of warm-blooded animals. It is, of course, evident that the development of hair or feathers is only possible where the animals lead a terrestrial life, while those which have adopted an aquatic life, *e.g.*, the whales and their near relatives, show a partial relapse into the old state.

Moreover, the fact that the warm-blooded animals were entirely absent during the earlier geological periods, so long as the surface-temperature of the globe was high, and the observation that the functions of hair and feathers are of vital importance in the cold climatical zones of our planet, show that the above mentioned stimulatory effect upon the skin can only he due to *low* temperatures, and that therefore the highest members of the vertebrate group, viz., the warm-blooded animals, must have first appeared in *cold* countries. Further, we have to distinguish between two widely separated cold zones, one situated in the northern, and the other in the southern, hemisphere. The descendants of the "antarctic" warm-blooded animals, as we may call them, seem to be the edentate and the monotreme mammals, as well as the birds belonging to the ostrich group ; while probably all other mammals and birds living at the present time are of "arctic" origin. It is interesting to note that the "antarctic" forms show well pronounced reptile (saurian) features which the "arctic" animals do not possess. The scales and teeth of the edentates, and the skull and spinal column of the ostrich-birds, may be mentioned in this respect.

As regards the formation of hair and feathers, it is clear that these organs of the skin, consisting of horny substances, require a certain protoplasmatic disposition, which I call *keratogenous.* Without this disposition the formation of hair and feathers is impossible. It is therefore evident that this kind of germ-plasma must be associated with the calorigenous disposition of which I have spoken above. The development of hair and feathers was a natural consequence of a combination between these two kinds of plasma. In this connection it is important that chemical analysis has established a difference in substance between the calorigenous egg-protoplasm of the warm-blooded birds, and the non-calorigenous

plasma-modifications of the eggs of the cold-blooded lower classes of the vertebrates, such as amphibia and fishes.

If we now compare the protoplasmatic disposition of the lower groups of animals, *e.g.*, of the rhizopods, with that of the higher groups, *e.g.*, the vertebrates, we recognise that one of the differences between the two is the much greater sensibility of the higher developed protoplasm to external influences. Whether the protoplasm of a rhizopod is in contact, or not, with water containing air does not in the least affect it ; while the protoplasm of the vertebrates is in this, and in many other respects, exceedingly sensitive. Very small changes in the internal movements may modify the highly developed protoplasm and produce characteristic secretions. Thus, when the protoplasm of the vertebrates is completely at rest, the chondrigenous disposition is developed ; when moderate movements take place, collagenous and elastic secretions make their appearance ; and, finally, when the intensity of the movements becomes greater, the secretions remain liquid and contain fibrine.

These results lead us to the following law : *The metamorphosis of the germ-plasma, in the course of phylogenetic animal development, is throughout characterised by an increase of the sensibility of the germ-plasma to all external agencies, and by a corresponding increase of the lability of its chemical composition.* This view includes, of course, the conception that the higher differentiation of the germ-plasma is due to its greater sensibility to external influences.

As we have good reason to believe that everything which affects the animal *in toto* also influences the protoplasm, we may adduce the well-known fact, that the sensibility of an animal to external influences increases if we protect it as much as possible from the attacks of these influences, thus producing a *weakening* effect upon the body. On the other hand, the sensibility of an animal decreases the more it becomes *hardened* to all sorts of exposure. Consequently there is little room for doubt that the same contrast of "hardening" and "weakening" exists when we compare the *germs* of lower and higher animals. For example, the eggs of fishes and amphibia are developed under conditions of much greater exposure than the eggs of all other vertebrates.

Proceeding further, we again find this contrast between reptiles and birds: the eggs of the latter require incubation, while those of the former usually do not. The highest vertebrates, the mammals, develop their eggs only within the maternal body, where they are protected from all external influences. This encasement of the germ-cells must necessarily have a weakening effect upon them, while, at the same time, it produces higher differentiating capabilities of the germ-plasma. Among the external agencies from which the germ-plasma requires to be protected, in order to reach the higher degrees of differentiation, I may mention not only the influence of the various substances composing the surrounding media, but also that of the kinetic forces (forces causing motion). In the vertebrate group we have in this respect to chiefly consider one kind of motion, viz., the oscillations in the temperature of the surrounding media, and their stimulating influence on the animal body. I am decidedly of opinion that this is the correct explanation of the problem, because all *warm*-blooded vertebrates are superior to the *cold*-blooded ones as regards height of organisation, as well as differentiation of the germ-plasma. The body-temperature of the warm-blooded vertebrates is to a great extent independent of the temperature of the surrounding air, and the sexual cells are always well protected against any oscillations of temperature; while the cold-blooded animals are more or less subject to all changes of temperature of the surrounding media. This observation is another proof that the better the sexual cells are protected, the higher will be the development of the animals to which they belong. In conclusion, I may mention yet another circumstance, viz., the *synthetic* influence of *warm* blood. Chemistry teaches us that the prolonged influence of moderate degrees of heat is one of the most powerful means for the synthetic formation of higher organic compounds. This again shows why the warm-blooded vertebrates, with their constant high temperature, are so much better developed than their cold-blooded relatives.

## XIII.—THE INFLUENCE OF THE FORCE OF GRAVITATION ON THE DEVELOPMENT OF THE ANIMAL KINGDOM.

(1876.)

I HAVE already stated that the force of gravitation may influence the form and development of an animal in three different ways. The most important of these is the separation of the various constituents of the germ-plasma according to their specific gravity.

It is a remarkable fact that, although many investigators of embryological problems have noticed and described the phenomena in detail, no one seems to have recognised the importance of gravitation in connection with one of the greatest problems of modern biology.

We have first to consider the fact that most—probably all—multicellulate animals are already *geocentrically differentiated* in the ovum, *i.e.*, one-half is specifically lighter than the other ; and so soon as the ovum is suspended in a liquid, the half which is of greater specific weight is always turned towards the centre of the earth. This fact becomes still more important if we remember that the yolk-ball of most animal ova is suspended in a suitable liquid in such a way that, whatever the position of the egg, it can follow the direction indicated by the difference of the specific weight. For example, the almost liquid albuminous coverings of the large meroblastic eggs of the sauropsida (birds and reptiles) allow the germ of the egg to find its proper place at the top, in whatever position the egg may be.

Further, nearly all investigators report that the eggs of other animals, which have only a small yolk, show a contraction of the yolk previous to its cleavage, the effect being that a liquid layer is produced between the yolk-ball and the chorion ; and this layer allows the yolk-ball to always assume the same position, viz., with the heavier half turned to the centre of the earth.

We will first discuss the cause, and afterwards the consequences, of this geocentric differentiation.

It is very important that we have here to deal with a *polar* difference of the animal body. Eggs which contain a considerable quantity of pigment, *e.g.*, the eggs of the amphibia, show this difference plainly, the pigment, as the embryonal development proceeds, being principally in the upper hemisphere, which is specifically lighter, although originally the pigment was equally divided in the yolk. The eggs of birds and reptiles invariably have the white yolk in the upper, and the heavier yellow yolk in the lower, hemisphere. The yolk of the eggs of many fishes contains large drops of fatty substances, which are always in the upper hemisphere.

On the other hand, the so-called granules and tabules of the yolk, which probably consist of vitellin, emydin, ichthydin, etc., are mostly found in the lower hemisphere, and consequently the lower hemisphere of eggs without pigment appears less pellucid than the upper one. Pigment itself is one of the specifically lighter substances contained in protoplasm. These differences are due, without exception, to the geocentric differentiation of the egg, and the force of gravity is the sole cause of this arrangement. There are three reasons why the germ-plasma possesses this geocentric tendency, from which the differentiated protoplasm of grown-up animals is free. The principal cause is the more liquid state of the germ-plasma, as previously explained. On account of the large proportion of water, the germ-plasma behaves like a liquid, *i.e.*, if it is allowed to stand at rest, the particles suspended therein are geocentrically differentiated according to their different specific gravities. Secondly, we have already seen that one of the characteristic features of germ-plasma is its small degree of contractibility, and this greatly favours the tendency to stand at rest, and to differentiate accordingly. The third reason is the considerable size of the egg-cells, as compared with most of the other isodiametrical cells of the animal body : the greater the distance through which a plasma-granule has to pass in the direction of the geocentric differentiation, the less the probability that some temporary motions of the protoplasm will prevent this process of differentiation.

In order to fully understand the important consequences of this geocentric differentiation of the egg, we must remember that the yolk of an egg is a mixture of two substances which are morphogenetically very different from one another. The active substance is the living protoplasm, while the yolk-granules, fatty globules, etc., play only a secondary and passive part, principally in connection with the nutrition of the embryo. This difference between the formative yolk and the nutritive yolk of an egg has long been known to embryologists. Further, it has been shown by various investigators to exist, not only in meroblastic, but also in holoblastic eggs, *i.e.*, it is a property of *all* animal eggs.

In considering the morphogenetic consequences of this geocentric differentiation, the first and principal question is : Which part of the egg contains the formative yolk ? In dealing with this question, we find the further interesting fact, that we have not only a geocentric, but also a concentric, differentiation before us, and that the latter considerably influences the former. This concentric differentiation is especially shown in the development of the articulate animals, and we observe that the formative yolk constitutes the surface, and the nutritive yolk the interior, of the egg-ball. The geocentric differentiation, on the other hand, produces at a certain point of the surface of the egg an *accumulation* of the formative yolk, and a corresponding diminution at the point diametrically opposite to the former. Two cases are possible, both of which have been actually observed. First, whenever the nutritive yolk is specifically heavier than the formative yolk, the accumulation of the latter takes place at the geocentrifugal pole of the egg. This occurs very frequently. Secondly, the accumulation of the formative yolk at the geocentripetal pole must take place as soon as the nutritive yolk is specifically lighter than the formative yolk, and this is the case when the former consists of fatty substances. *Haeckel* has observed and described a species of Ganoid fishes which show this peculiar arrangement. He says,*—"The greater part of the interior is full of nutritive yolk, consisting of two substances which are completely separated. The first is a large and pellucid

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* *Haeckel*, Gastraea Theorie, page 95.

albuminous ball, and the second a small ball of fatty matters. These fatty matters are the lightest portion of the egg, and consequently they form the uppermost part of the floating egg, while the small formative yolk is situated at the other pole of the axis of the egg."

The morphogenetic difference of these two poles of the geocentric axis is due in all cases to the fact that at one pole an accumulation of the formative yolk, and at the other pole an accumulation of the nutritive yolk, takes place. I therefore call the former the active, or animal, pole, and the latter the passive, or vegetative, pole.

This geocentric differentiation renders it impossible for the germ to grow concentrically, which is only practicable, more or less, so long as the embryonal cells contain sufficient water to allow of their changing their positions. But so soon as the amount of water becomes less, the antagonism of the two poles completely changes the form of the embryo; and hence we come to the conclusion *that the force of gravitation is, as regards time and importance, the first morphogenetic factor of the ontogenesis of animals.*

Before we proceed further we must direct our attention again to a point which we have already discussed, viz., the importance of the plasma granules. Physiologically these albuminous granules play an active part, while vitellin, yolk-granules, fatty globules, etc., are, physiologically considered, more or less impediments. This may now be expressed as follows :—So long as the passive yolk-granules are equally divided in the germ-plasma, they impede the active properties of the latter, and the beginning of the animal development must be preceded by local "purification" of the germ-plasma from these obstacles. This is effected, first by the concentric, and afterwards by the geocentric, differentiation. *Inter alia*, these facts throw light on the very important biological problem of *parthenogenesis*. It has been asked why in this case development does not take place, without fertilization, immediately after the separation of the parthenogenetic cells from the ontogenetic embryonal cells? Why do the former remain latent for some time, and commence the ontogenetic process only after a certain interval?

I reply to these questions as follows :—

During the first period after the separation of the parthenogenetic cells from the embryonal cells, all the conditions are wanting for the geocentric and concentric differentiations, which depend, as we have seen, on an increased amount of water, and on a larger size of the yolk-ball. Moreover, the surrounding media are of great influence, and they can, of course, only act after the egg has changed its original position. I believe that by this explanation parthenogenesis is brought within the scope of the normal kinds of propagation and of the theory of descent.*

Thus we arrive at the conclusion *that fertilization is neither the only, nor the most general, cause of animal development.* Instead, we have the following law :—*The concentric and geocentric differentiations of the yolk, produced by the force of gravitation, are the universal causes of animal development. In some instances (parthenogenesis) they are quite sufficient to explain the embryonal development, while in the majority of cases they are supported by the effects of fertilization.*

The immediate consequence of the physiological effect produced by geocentric differentiations is the *morphological* influence on the distribution of the various substances, and on the differentiation of the tissues of the germ during its development. This may be appropriately expressed as follows :—The animal pole of the geocentric axis is *the centre of growth, i.e.*, the spot where the vital activity is greatest ; therefore this axis greatly influences the distribution of the various substances of the embryo. This influence is noticeable from the very beginning of the embryonal development, even at a time when no other morphogenetic influence can be observed, and consequently the *fundamental form* which the germ assumes in the course of its ontogenesis is principally due to the geocentric differentiation.

In order to understand this fully, we must first remember that the centre of growth produces an expansion, by which all those parts which are not situated in the pole itself are shifted from their original positions. Provided that the resistances in the parallel circles surrounding this pole are equal in all meridians,

* Compare also chapter II., p 10.

the expansion produces a regular and circular distribution of the substances round the pole ; but as soon as the resistances become unequal on certain meridians, a different form of the embryonal development must be the result. The expansion of the centre of growth is the active factor, and the tension of the tissues is the passive factor, in the development. Consequently this pole has a predominating influence on the distribution of the materials of the body. As long as the embryonal cells can easily change their position, they will expand over the yolk-ball, or rather over that portion of it where the cleavage of the embryonal cells is slower. They will grow round this part, or—as in the case when a gastrula is formed—the embryonal cells of the animal pole will produce a groove in the vegetative half, owing to their more energetic growth. By this means the entodermal layer comes into existence. But so soon as the yolk-ball is surrounded, or when the formation of the gastrula is complete, *folds* make their appearance, on account of the greater numerical growth at the animal pole of the embryo.

Another factor, to which the appearance of these folds is partly due, is the increase in the adhesivity of the protoplasm, owing to the above-explained diminution in the amount of water. Consequently, the cells which are not situated in the pole itself can no longer shift under the influence of the pressure originating in the animal pole ; and the germ-disc becomes folded, *the centre of growth thus becoming the centre of the formal development.*

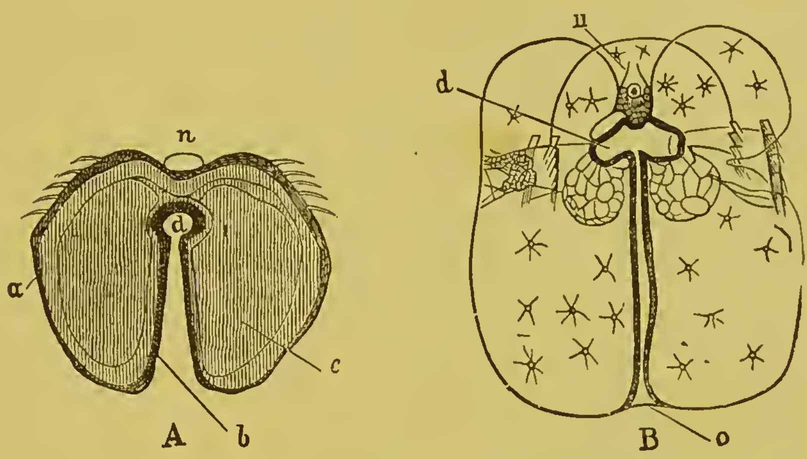
A third factor in the production of these important folds is that, if a circular cell-layer surrounding the pole is shifted "expolarly," it has to cover a larger space than before. The converse happens if such a cell-layer approaches the pole. Hence, in the first case, the space on which this cell-layer can develop the products of its numerical growth increases, while in the second case it decreases. There is thus a great contrast in the embryonal disc between circumference and centre, *i.e.*, the centre tends to expand, and the circumference to compress, the embryonal materials in question. Professor *His'* view, that the embryonal cells congregate at the centre, is correct in respect of the cells of the mesodermal layer, but not as regards the first folds of the embryo, which appear in the exodermal layer. On the contrary, the cells originating in the

centre are prevented by the tension of the tissues at the circumference from expanding in a plane, and are thus compelled to remain where they are. The natural consequence is that the germ disc becomes thicker in the middle; and as soon as the mobility of the cells decreases, *a fold, which is exactly situated in the centre, makes its appearance.* I call this fold the *neural fold*, because the cells of which it is composed become the centre of the nervous system. That this is an actual fact has been positively proved in all vertebrate animals, as well as in the tunicates and comb-jellies (Ctenophoræ) ; and probably the other *enterata* are also provided with this important fold.

Before we proceed to discuss the influence of the geocentric differentiation we must consider the ontogenetic stage, at which the neural fold makes its first appearance. *Haeckel* has appropriately characterised the first ontogenetic stages as those of the *morula*, *blastula*, *gastrula*, etc. Following his example, I define the ontogenetic stage of the formation of the neural fold, at the animal pole of the geocentric axis, as the *neurula stage.* This definition becomes the more important, as there is a distinct homology between the formation of the gastrula and that of the neurula, which, so far as I know, nobody has ever pointed out before. The mechanical factors are also similar, viz., a disproportion between the growth of the walls and that of the centre, or, as *His* defines it, neurula and gastrula are caused by the principle of unequal growth. In the light of my own explanation this reads as follows :—*Neurula and gastrula are both caused by the geocentric differentiation. The gastral fold appears at the vegetative pole in consequence of the shifting of cells from the animal pole to the vegetative pole. Later on, when the cells cannot be shifted so easily, the effect of the pressure originating at the animal pole, and now limited to the animal hemisphere, produces the neural fold.*

An examination of the neural folds known at the present time shows that they differ considerably. These differences are of the greatest importance to our knowledge of the phylogenetic and ontogenetic development of animals ; and as they are analogous to those of the gastrula stage, discovered by *Haeckel*, it will be useful to compare some neurula forms with the corresponding gastrula

modifications. The simplest form of the gastrula is that called by *Haeckel* archi-gastrula. Analogous is the archi neurula, which I prefer, however, to call *ortho-neurula*, thereby expressing that in this case the neural fold is diametrically opposite to the gastral fold. This important form of the neurula seems to be limited to a single group of animals, viz., that of the comb-jellies (Ctenophoræ), *see Figure* (according to *Kowalewsky*).




A. Neurula of a comb-jelly (Eucharis), perpendicular section; *a* exoderm; *n* formation of neural fold; *b* entoderm, forming gastral fold; *c* mesoderm; *d* cavity of intestine.

B. The same animal, somewhat older; the neural fold now forms the otolith-bubble and ganglion *n*, while at the entrance of the gastral fold the mouth *o*, of the animal appears.

The comb-jellies are a much neglected group of animals, but they are probably the *oldest living representatives of all those enterata the ontogenesis of which shows the neurula stage.* We are no longer justified in regarding them as a mere appendix of the coelenterata. On the contrary, they illustrate a very important development in the history of the animal kingdom, as they are provided with the oldest and simplest form of the neurula stage. The neurula of the comb-jellies has a very simple form ; it is a single ganglion surrounding the otolith-bubble (see figure). This diametrical position of the two poles of the geocentric axis explains the absolutely regular type of the comb-jellies, on account of which they have been arranged in the same systematic group as the disc-jellies.

The neurulae of all other animals differ considerably from the ortho-neurula of the comb-jellies, inasmuch as the gastral and the neural folds are *not* diametrically opposed to each other. For this reason I call them *lordo-neurulae.* The purest and simplest lordo-neurula is that of the tunicates. This *primary* lordo-neurula, as we may call it, has one thing in common with the ortho-neurula of the comb-jellies, viz., that the neural fold is of a funnel or tube-like shape, with a circular basis. For this reason I define it as *lordo-neurula tubiformis.* The neurulæ forms of the vertebrate animals are quite different. Their characteristic feature is the much larger basis of the neural fold. Instead of the small funnel-shaped fold, they have either a *linear* fold (*e.g.*, Amphioxus), or a large disciform groove, which, at a later stage, forms a long furrow. Compared with the neurula forms previously described, this modification not only differs as regards position, but also as regards size : the former are *micro*-neurulæ, while the lordo-neurulæ of the vertebrate animals are *macro*-neurulæ.

Before we continue this formal analysis we must answer the question by what properties the neuruligenous germ-plasma differs from the gastruligenous, and the macro- from the micro-neuruligenous plasma? It is evident that we have here a quantitative, rather than a qualitative, difference. This quantitative difference consists in the greater or less proportion of matter on which the adhesivity of the cells and the perviousness of the germ-layers depend. If simply a gastral fold is formed, as in the case of the sea-nettles and sponges, both germ-layers must grow and shift *equally* after the gastrula has been formed. This is only possible if the protoplasm has a high degree of permeability, as by such means alone can a greater physical difference between the exodermatic and the entodermatic layer of the body be prevented. An important step in this direction is the development of pores, which, *e.g.*, characterise the sponges, while the sea nettles show nothing but a higher degree of the faculty of swelling. The result is, in both cases, the same, viz., the greater proportion of water in the protoplasm. The question becomes still clearer when we examine the mechanical process of neurulation. This process is in the first place based on the difference in tendency to expansion of the entodermatic layer which forms

the gastral fold, because, so soon as this difference reaches a certain limit, one of two things must happen :—

1. Either the distance between the two concentric layers increases, which can only be the case when a sufficient quantity of liquid enters the cleavage-cavity which separates both.

2. Or, if the pressure of this liquid is negative, a fold of the exodermatic layer must make its appearance, and this is the neural fold.

As the cleavage-cavity has no outward opening, the increase in its contents is simply a question of the permeability of the germ layers, and this permeability is in direct proportion to the amount of water which the protoplasm contains.

The difference of growth between the exodermatic and entodermatic layers is also based upon this fact ; because (as the gastral porus is very small) the difference increases in proportion to the resistance which the protoplasm offers to the entrance of the outer medium. Moreover, we have to take into consideration the amount of shifting of the exodermatic cells : the greater this shifting, and the more the liquid in the cleavage-cavity increases, the less is the probability of a negative pressure in the latter. This also explains the difference between micro- and macro-neurulation ; the more quickly the shifting properties of the exodermatic cells decrease, the greater will be the tendency of the exodermatic and entodermatic layers to expand ; and the more difficult it is for the liquid of the cleavage-cavity to follow this difference of expansion of the two germ layers, the earlier and larger will be the formation of the neural fold.

It will be necessary to investigate analytically the amount of water contained in the protoplasm of the different gastrulæ and neurulæ.

Returning to the *formal* part of our problem, we have now to examine the differences in the macro-lordo-neurulæ of the vertebrate animals. The Amphioxus has a simple, primary neurula, the fold being a linear furrow, which I define as *macro-lordo-neurula sulciformis*. The primary neurula form of the higher developed fishes is similar, except that in this case we have a closed fold, instead of an open furrow, and that, near to the cerebral pole, the neural fold becomes disciform. For this

reason I describe this modification as *sulco-disciformis*. The neural fold of the amphibia and amniotes has from the very beginning a disciform groove, which is due to the so-called medullary plate of these groups of animals. I therefore name this modification macro-lordo-neurula disciformis. During the later ontogenetic stages, this disc becomes pear-shaped, and its thinner end gradually assumes the shape of a linear furrow, well known as the so-called *primitive furrow*. The proper designation of such a neurula will therefore be *discosulciformis*.

I remark that we have definite and accurate knowledge of all these neurula forms.

From the promorphogenetic point of view, the principal difference between these neurulæ is that of the ortho- and of the lordo-neurula. The neural porus and the gastral porus, are, so to speak, the pillars of support to the two centres of growth which produce an active or passive pressure of growth. But as every pressure of growth acts at the point of the least resistance, and as in a sphere this lies in the direction of the longest possible rectilinear distance, *i.e.*, in the diameter of the sphere, it follows that a pressure which acts on any point of the circumference of the globe is perceptible at the point diametrically opposed to it. Now, if on the surface of the globe two points of pressure are diametrically opposed to each other, the conditions of pressure will be equal in all parts of the globe which are at right angles and at equal distances from the diameter connecting the two points of pressure. We thus have a primary and single axis as the fundamental form of the ortho-neurulæ of the comb-jellies. But if the two points of pressure are at an oblique angle to each other (with reference to the centre of the globe), the effective forces originating from them may cut one another under any angle in the centre of the globe, and each of them will have a separate point of anti-pressure. These four points determine two axes of growth, and a principal plane in which both axes and their poles are situated. Consequently, a body of this kind has a principal plane, with the parts of the body equally and symmetrically arranged on each side. The *orientation* of this principal plane, which is invariably perpendicular during the ontogenetic development of most animals, is of great importance.

The most interesting promorphogenetic question in connection with this fact is the following: What is the cause of the transformation of the geocentric *axis* into a geocentric *plane?*

It might at first be supposed that a change takes place in the centre of gravity, for we know that the germs of the eggs of the amphibia alter their position by 90 degrees during the transformation of the geocentric axis into the geocentric plane. The result in this case is that the gastral porus, which was originally located at the centripetal pole of the geocentric axis, is now situated at the end of a horizontal axis. But meroblastic eggs do not exhibit this change of position by 90 degrees; and a simple observation shows that it is not the cause, but the consequence, of the matter under discussion. The centre of gravity is affected by the greater development of the exodermatic layer in a certain meridian, and the change of position by 90 degrees is the consequence. Moreover, this eccentric development has been proved to take place as early as the gastrula stage, which shows that the cause, whatever it may be, acts at a very early period of the embryonal development. In examining external natural influences, we notice a factor which has great effect on the vegetable kingdom in the direction indicated, viz., the sunlight; and if we investigate the various conditions of the development of animal eggs, we find many cases in which the eggs (*e.g.*, insect eggs) are fixed to the surface of an oblique or perpendicular plane. In all such cases we have to deal with a *fixed* axis which cuts the geocentric axis obliquely, and which may produce a differentiaticn of development. Moreover, when animal eggs are developed in water which is in constant motion, we have another active force which cuts the geocentric axis obliquely. In connection herewith it is interesting to note that even such fishes as are accustomed to live in still, stagnant water, place their spawn where the water is in constant motion. Ocean currents and tides are doubtless of great influence in this respect. The floating eggs of maritime or lacustrine fishes have neither a fixed axis nor an axis of motion; but the light and its influence must not be underestimated, as the direction, with very few exceptions, cuts the geocentric axis at an oblique angle.

The problem becomes more complicated so soon as we have to deal with eggs which are developed in the interior of the maternal

body.* But even in such cases there are factors which favour a development in other directions than that of the geocentric axis, *e.g.*, the position of the uterus of viviparous animals.

Insect eggs which are developed in the interior of plants are subject to the influence of external heat, which either acts on the surface or on the southern side of the plant.

I must confess that in eggs which are developed subterraneously, I am, at present, not aware of any factor which acts in a direction oblique to the axis of the earth. There are other cases in which an obliquely acting factor has not yet been discovered, and I hope that what I have said will lead to further investigations on this interesting subject.

I will not omit to mention that the eggs of a great many animals, *e.g.*, those of most birds and reptiles, as well as those of a large number of insects, are not spherical, but elliptical, and that their axis is, as a rule, at right angles to the direction of the force of gravitation.

* Compare chapter VII., page 46

## XIV.—SYMMETRY AND REGULARITY AS THE FUNDAMENTAL PRINCIPLES OF SYSTEMATIC ZOOLOGY.

(1857.)

AT the beginning of my Zoological Studies I found it very difficult to connect the body-form of a sea-star, a sea-nettle, or a polyp with that of a mollusc, or of a vertebrate or articulate animal. There are a number of characteristic features which may be added one to another, but which cannot be systematically arranged. When I became acquainted with *Agassiz'* views on the symmetrical forms of the echinoderms, his arguments failed to convince me, as a circle cannot be considered a truly symmetrical form because it can be divided into two symmetrical semi-circles. Later on, I was pleased to find that *Burmeister*, in his "Zoonomical Letters," acknowledged the importance of the distinction between symmetrical and radial animals, by accepting these two forms as the second principle of his systematic arrangement. But when I expected him to give proofs for this view, I was disappointed, as he only used the words, but gave no definitions.

In trying to myself define the respective positions of radial and symmetrical animals, I came to the conclusion that these types are fundamentally different. I found that this view has been supported by everyone who has considered the various types of animals without prejudice, and *Cuvier* was very emphatic on this head. But nobody has conclusively proved the accuracy of the theory, and when it has been attacked by some scientific authorities, it has never, so far as I know, been properly defended. Two reasons have been given to prove its *inaccuracy*. First, it is assumed that an uninterrupted connection exists between all animal forms, from the lowest infusoria to the highest vertebrates; and as the great majority of these forms are symmetrical, the

symmetrical type is regarded as the only fundamental one. This is evident from the following statement by *Agassiz*, who was the first to believe that he had proved the symmetrical structure of the radial animals. He says*:—"The regular radial arrangement of the body-parts of most of the radiata is the reason why it is so difficult to find a proper terminology. This induced me to commence with the examination of those forms which have little to do with the radial type, and in which, on the contrary, the front and back parts, and right and left sides, are easily distinguishable. Starting from this point, I endeavoured to find the almost imperceptible transitions which connect these symmetrical forms with the regular, and even with the globe and star-like forms."

The second reason why the view in question is regarded as incorrect is, that no zoologist has ever given a clear and comprehensive definition of the radial and symmetrical forms. In order to arrive at such a definition, we will first examine these two forms in their strictly mathematical sense. Three dimensions are necessary to define a body, and two planes correspond to each dimension. Applying this to zoology, we can say :—Radial bodies are those in which the planes belonging to one dimension are fundamentally different, while the planes belonging to the two other dimensions are fundamentally equal. On the other hand, symmetrical bodies are those in which the planes of two dimensions are fundamentally different, and only those of the third dimension are fundamentally equal. The terms *fundamental difference* and *fundamental equality*, as I use them here, refer to the principal properties of organic and inorganic bodies. Planes which are fundamentally equal may be *formally* very different. For example, two planes of a crystal may be quite different in their size, circumference, &c., but they may nevertheless be fundamentally equal as regards their hardness, their optical, magnetical, and other properties. In the same sense, two fundamentally equal planes of an animal may be different as regards size and shape, and yet, if they have the same organs and the same animal functions, they must be regarded as fundamentally equal, although *formally*

* Mem. De La Soc. des Sciences Nat. de Neufchatel T.I., page 69.

different. The corresponding explanation of course holds good for planes which are fundamentally different. Applying names to these definitions I am of opinion that it is best to describe fundamentally different planes as *polar planes*, and fundamentally equal planes as *parallel planes*. We thus arrive at the following definition :—*A body which has two pairs of polar planes and one pair of parallel planes is symmetrical, while a body which has one pair of polar planes and two pairs of parallel planes is regular.* If we connect every two polar planes by a straight line, we may call this line *an axis*, and by these means we can express the above definition very clearly and shortly, as follows :—*Diaxial bodies are symmetrical, monaxial bodies are regular.*

We have now to see how this definition, which is here given *in abstracto*, can be applied to the animal body. Instead of mathematical planes, we must take into consideration the different parts of the body. This seems easy, but the difficulty of finding appropriate names for the various parts of the body is very great, because we have at present no systematic names for them. It is a serious drawback that the nomenclature of the parts of the animal body in general are either taken from certain organs, or from the customary description of the vertebrates. Both these methods are quite inadequate, but by the aid of our definition we shall be able to explain the differences in question.

First we have to deal with the pairs of polar planes. The principal pair of polar planes of most animals is that pair which is characterised by the *head* and by the *anus*. The head, as it is always called in the description of diaxial animals, is usually characterised by the organs of nutrition, and by those central parts of the nervous system from which diverge the nerves of the higher senses. I call this pole the *head-pole*, although this definition cannot be applied to monaxial animals. By analogy, I call the corresponding pole the *hind-pole*. Frequently the anus forms a part of this pole, but not necessarily; for it may not only be absent at this place, but it may change its position and proceed even as far as the head-pole. Moreover, the hind-pole is usually characterised by the organs of generation; but their position is also not stationary, as their embryonal development only takes place after the other organs have been fully developed. On the whole.

the organs of the hind-pole show a much greater tendency to vary than those of the head-pole, and consequently the description of the former is much more difficult.

Turning now to the second pair of polar planes, which only occurs, as we have seen, in diaxial animals, it is characterised by the dorso-ventral developments of the vertebrate and articulate animals ; while in the peculiar development of the molluscs it is represented by the foot and the mantle-sack. One of the two poles of this pair of polar planes is usually characterised by the organs of locomotion, and by those parts of the nervous system which preside over these organs. I may therefore appropriately call this pole *the animal pole.* The corresponding pole is that part of the body which contains the intestines, and I therefore call it *the vegetative pole.* It is evident from what I have said that I understand by these different poles, not merely the superficial planes, but the actual parts of the body with all their organs and systems. My object is to disintegrate the whole body of an animal into its principal parts, called poles, as explained.

Our next question is, whether the pairs of parallel planes also represent separate, well defined parts of the animal body. This is clearly not the case in the groups of the vertebrates, articulates, cephalopodes, and cephalophores ; but in the groups of the acephales and brachiopodes we find well developed and characteristic parts of the body, corresponding with one pair of parallel planes. Each side consists of one-half of the mantle, with its shell, tentacles, gill-leaves, &c., &c. On the other hand, neither the acephales nor the brachiopodes show any polar development, and the whole body consists of two parallel parts.

We have thus arrived at the following conclusion :—

*Diaxial animals either consist of two pairs of polar planes or of one pair of parallel planes; monaxial animals consist of one pair of polar planes only.*

We have now to answer the question :—*What are the characteristic features of either of these groups?* This is, for several reasons, a question of great importance.

First, many grown-up animals show their polcs less distinctly than during their development, and therefore some means are necessary by which the poles can in every case be recognised.

Second, the question has never been considered properly ; and this is the principal reason why *Agassiz*, and, in part, *Johannes Mueller*, have regarded the radial animals as symmetrical.

Our definition states that the corresponding poles are fundamentally different, and this, applied to the animal body, means that an organ which is situated at one pole cannot also occur at the other pole. Hence, if an animal has two equal organs in two formally different planes, these planes cannot be polar. The group of the holothuria forms a very good illustration of this. They show what appears to be a dorso-ventral development ; but in both parts of the body they have the same ambulacra, and consequently the planes are not polar. Hence we have to regard the holothuria as monaxial animals. Moreover, it follows from my definition that only fundamentally different points can be connected by what I have termed an axis, and that the points which are situated within the axis are different from those lying on both sides of the axis. Points equidistant from the axis, and corresponding to one another, are equal ; and where only one axis exists there may be as many corresponding points as there are equal distances. In the animal body, we have, of course, to consider body parts instead of mathematical points ; and we find that an organ lying within an axis does not exist in parts, but that all other organs exist in plurality, and their number may be as great as there are equal distances from the axis. As a matter of fact, however, this number is always limited, as an indefinite repetition of any single organ is inconceivable. Experience shows that the most frequent figures are 4, 5, 6, 8, &c., hence, all monaxial animals show the following characteristic feature :—*They have one "unpair" organ, the so-called axial organ, while all other organs occur in plurality, and are situated in a plane perpendicular to the axis.*

In diaxial bodies the axes cross each other, and consequently an axial plane is determined, which, however, only connects different parts. This axial plane corresponds in every respect with the axis of the monaxial animals, viz., all organs situated in the axial plane, and all secondary organs which are developed in the direction of the axis, do not exist in pairs, because they cannot repeatedly occur within the axial plane, and because they differ from the

organs situated on both sides of the plane. The latter organs correspond to one another in equal distances from the plane, and therefore all such organs must be present in pairs. Further, as several parts may be situated in the plane, a diaxial animal may have more than one axial organ. And this is in fact the case: we find the heart and the intestines, which both belong to the vegetative pole; and, in addition to these, the group of the vertebrates has a third axial organ, the *chorda dorsalis*, which belongs to the animal pole.

If we examine the parallel planes, we know that every point in the one must have its corresponding point in the other; therefore in all cases of this kind the number of equal organs must be either two or a multiple of two. Organs can only be unpaired if they lie in the tangential plane of the two parallels, and they may then be either completely unpaired, or the two original parts may be combined, forming one organ, but in such a way that the duplication can still be recognised. This duplication, however, has never been found in the direction of the line which connects the mouth and the anus, but only in a line perpendicular to it.

This fully explains the peculiar structure of the heart of the *Acephala*, where the auricles lie right and left from the ventricle, and not in front of the latter, as the cephalophora have it; the peculiar duplication of the heart of the *Arca* is likewise explained by this argument. It follows from the polarity of the parallels in the two other dimensions, that an organ cannot be repeated within the same parallel; but in the group of the *Brachiopoda*, the parallels of which are not polar in both dimensions, but only in one, each parallel must necessarily have two equal points in the direction of its parallel dimension, in equal distances from both parallel ends. Each parallel must therefore have a pair of organs, or paired organs. Hence the number of organs within a parallel must be *divisible by four*. But the organs which are situated in the tangential plane of both parallels must be *double*. An unpaired organ can lie only in a line which is obtained when the tangential plane of the two parallels is cut by another plane, dividing both parallels into two equal parts. But as only one organ can lie in a line, the brachiopoda have only one axial organ, viz., the intestinal

canal. The number of all other organs must be divisible either by two or by four. Comparative Anatomy shows that these statements are correct.

We therefore arrive, except as regards the brachiopoda, at the following general conclusions :—*Monaxial animals have only one axial organ, and their number of organs is not divisible by two ; diaxial animals have more than one axial organ.* These two facts enable us in every given case, the brachiopoda excepted, to determine whether an animal is monaxial or diaxial.

Moreover, these facts completely overthrow *Agassiz'* theory of the symmetrical structure of the echinoderms and polyps. I am sure that any one who compares my explanation with the fundamental definitions of *Agassiz'* theory will become convinced that the latter is incorrect, because an organ which is in reality unpaired, and therefore an axial organ, cannot exist in plurality. It is absurd to describe *one* of the five ambulacral lines of a sea-urchin as unpaired. An echinoderm has in reality only one unpaired organ, and that is the intestinal canal ; all other organs and body-parts are present in plurality, and therefore all echinoderms are monaxial animals. With the help of these explanations, we are in a position to determine with certainty which groups of the animal kingdom are monaxial, and which are diaxial, viz., the vertebrates, articulates, and molluscs are diaxial, while the echinoderms, jelly-fishes, and polyps are monaxial. All animals must therefore be divided into *three* groups, of which the first two consist of the animals just indicated, while the third group embraces that low type of animals which have no axis at all, viz., the rhizopoda, infusoria, &c. These three groups are well-defined natural groups, without any transitions.

To show that this is actually the case, it is necessary to also investigate the axial development of the different embryonal stages of representatives belonging to the first and second group. Nobody has ever tried to do this, simply because the fundamental differences of the grown-up animals have hitherto not been recognised. Practically speaking, we have to answer the following question : Has the embryo of a diaxial animal two pairs of polar planes or one pair of parallel planes ? and has that of a monaxial animal one

pair of polar planes? In the vertebrate group, *Bischoff* has proved this for the embryos of the mammals, *Baer* for those of the birds, and *Rathke* for the embryos of the fishes. *Rathke* has further proved that similar conditions exist in the development of the articulate animals. In both groups (vertebrates and articulates) the embryo shows the head pole and the animal pole. The first stages of the embryonal development of the worms are still incompletely known; but from the investigations of *Schultze*, *Burmeister*, and *Max Müller*, we know that the embryos of Arenicola piscatorum, of Polynoe, and of the leeches, show the head pole and the animal pole.

The details of the embryonal development of the cephalopodes are peculiar, but it has been proved by *Kölliker* and *Duges* that in this case also the head pole and the animal pole are distinguishable. *Karsch*, *Leuckart*, *Schmidt*, *Vogt*, and others have proved the same for the cephalophores.

It is evident that the head pole and the animal pole are the primary poles of the embryonal development, while the hind pole and the vegetative pole are not so well developed, and may therefore be described as secondary poles. Or it is perhaps more to the point, in this connection, to call the head pole and the animal pole positive poles, and the other two negative poles

Then we find that in all groups of animals which have so far been investigated, *the first stages of the embryo are represented by the positive poles, while the negative poles are represented by the yolk.*

As regards the Acephala, I have already explained that in this group the definition of a diaxial body is different from that of the other groups, because we have to consider the parallels, instead of the two pairs of polar planes, and their embryonal development proves conclusively that this is correct. *Carus* and *Quatrefages* have shown that the first differentiated parts of the embryos of the Acephala are the two halves of the mantle and of the shell, and that they appear on both sides of an impression which corresponds to the hinge of the shell, while, at their converging planes, the gills are developed. Hence, it is evident that the primary parts of the embryos of the Acephala are a pair of parallel

planes. This proves the correctness of my definition, and we can now say :—

*There are two kinds of diaxial animals, the first consisting of two pairs of polar planes, and the second consisting of a pair of parallel planes, which is either polar in the two other dimensions (Acephala), or polar in the one and parallel in the other (Brachiopoda).*

It is not my intention to deal here with the *tunicata*. I am of opinion that they should be completely separated from the acephala.* I believe them to form the connecting link between the monaxial and the diaxial animals, as, in spite of their almost symmetrical appearance, their structure is, in my opinion, closely related to that of the monaxial animals. As regards the latter, we have first to consider propagation by the formation of buds. The embryonal development of the echinoderms has been described by *Johannes Mueller*, who found that, in spite of the differences between grown-up animals and larvæ, all echinoderms have one characteristic feature in common, viz., that the part of the body which is first developed is always *one* pole. This pole is neither composed of two unequal parts (as is the case in the embryonal development of the vertebrates, articulates, and cephalophores), nor of two equal parts (as in the embryonal development of the acephales and brachiopodes). It consists of five or six fundamentally equal parts, arranged in a circle, which appear to be polar only in one dimension, the mouth of the animal being usually situated in the centre of the circle. The peculiar development of the asteroides and ophiolepis, as described by *Sars*, *Agassiz*, and *Krohn*, is not an argument against my explanation, as in these cases the embryos are attached to the ground, and their development is subject to this condition.

Embryologically speaking, monaxial and diaxial animals differ from one another as follows :—The embryonal pole of the latter either consists of two positive poles, which differ in their form and in the latter stages of their development, or of two equal parts

* This view, which *Dr. Jaeger* expressed in 1857, has been completely confirmed. The development and the systematic position of the tunicata, as indicated here by *Dr. Jaeger*, is one of the most conclusive proofs in favour of the Darwinian theory.—The Ed.

added to one another in the direction perpendicular to the longitudinal axis of the grown-up animal. The monaxial animals, on the other hand, have an embryonal pole, which consists of equal parts arranged in a circular disc, whose circumference is equal in the direction of a number of radii, which is fixed for every animal.

We have now to consider another embryological question of great importance, viz. :—Are there any fundamental differences between the monaxial and the diaxial types *before* the embryo comes into existence? There are two answers to this question, viz. :—

1. The embryo of a monaxial animal leaves the egg without showing any trace of being an organised body, while the embryo of a diaxial body commences its organisation in the egg itself.

2. After the completion of the yolk-cleavage, we distinguish in diaxial animals a central part, the yolk-ball, and a peripheral part, of the nature of a membrane. The former part is the first stage of the development of the intestines, and the latter that of the perisom. The result of the yolk-cleavage of a monaxial animal is a *homogeneous* embryo, without any central or peripheral differentiations.

We are now in a position to draw the following general conclusions :—

1. An animal which leaves its egg without any differentiation, and obtains its intestinal canal* while floating about, will become a symmetrical animal ; but if it be attached to the ground before the differentiation of the intestinal canal takes place, it will become a radial animal.

2. At the commencement of its embryonal development a monaxial animal is always attached to the ground ; and a diaxial animal approaches the monaxial type if its embryo is attached to the ground in its early development. It is evident from this that the ultimate cause of the *radial* type is attachment to the ground at an early embryonal stage.

3. Only monaxial animals propagate by the formation of germ-buds.

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* The position of which is perpendicular to the radius of the earth.

4. The axis which connects the head-pole and the hind-pole of the diaxial animals is in the great majority of cases *horizontal*, while the axis of the monaxial animals is *perpendicular*. Animals changing the position of their axis approach the opposite type; and organs which are developed after the change takes place are often similar as regards number and position to the type originally foreign to them.*

All these results point to certain *formative* influences which are of importance for the building up of the animal body. We see that the axial direction mentioned above is characterised by the position of the intestinal canal of many animals; while the other axial direction seems to be in connection with certain physical agencies, among which I may mention the influence of light. It is important, physically and physiologically, to examine all the factors which may have to be considered in connection with this subject, and to carefully study their influence on the development of organic bodies.

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* The great morphogenetic importance of the statements made by *Dr. Jaeger*, sub. 4., becomes evident if we compare them with *Dr. Jaeger's* subsequent discoveries on the morphogenetic influence of the force of gravitation, see chapter XIII.—The Ed.

# PART II.

# ANTHROPOLOGICAL.

## XV.—HUMAN VITALITY, AND THE EXCHANGE OF MATTER IN CONNECTION WITH ORGANIC LIFE.

(1878.)

IN natural science the opinion has long prevailed, that the chemical and physical processes which characterize the exchange of matter in organic bodies are of a different nature from the corresponding processes in inorganic bodies. In particular, the so-called *vital force* was considered to be different from all processes of inorganic nature. Recent discoveries, however, have disproved this theory; and one organic process after the other has been recognised to be the effect of forces which act precisely in the same way in organic and in inorganic nature. The unexplained processes of animal *inheritance* are the last refuge of this mysterious vital force.* A similar remnant of unexplained natural forces exists in respect of the so called animal soul, although a number of processes in connection therewith can now be fully explained.†

The human body has often been compared with an engine, and although this comparison has its shortcomings, it is useful for practical purposes, as it enables us to easily understand many processes which, without this comparison, would be more difficult to explain. We must, however, always bear in mind the great differences which distinguish a living body from a lifeless engine. Both body and engine consist of a number of single parts, which are capable of transmitting their motions from one to the other, their relation being that of effect and contra-effect. But all parts of the engine are lifeless, and can only conduct and transmit external motions. In connection with the engine there is a single part which creates the force and produces the motion, viz., the boiler. In the living body there are also certain parts which may be described as more or less lifeless, but they are of quite

* Compare chapter IX. † Compare chapter X.

subordinate physiological importance ; and the great majority of the constituents of the body consist of living substance, *i.e.*, they are capable in themselves of producing free and independent motion.

This leads us to another comparison, which is perhaps more to the point than that with the engine. The human body resembles a civilised state, in which each individual enjoys a certain amount of independent activity, and where the final result of all forces is the sum of these individual activities, subject to the principles of co-operation and division of labour. Consequently, we can only understand the functions of the human body after we have acquired a knowledge of those processes of life which take place in every single part of the living substance. We must therefore first study the elementary organisms of which the organs of the body consist, and to which they owe the possibility of producing vital activity and energy. These elementary organisms are not all equal to one another. Their forms differ greatly, and their chemical composition is subject to considerable variation. But they have one property in common, viz., that they consist of *living substance*, *i.e.* protoplasm, which is a compound of gelatinous consistency, with small granules irregularly distributed in the gelatinous matter. This living substance is *the bearer of all organic life*, and any attempt to explain human vitality, with its functions and conditions, must first show what protoplasm is, and how it acts. While inorganic bodies are chemically and physically characterised by a stabile equilibrium, the living substance is labile in this respect, and is subject, chemically and physically, to rhythmic disturbances, *i.e.*, its chemical composition is affected by the rhythmic changes of absorption, assimilation, and secretion of substances, a process defined in its totality as "exchange of matter." At the same time, the living substance alters its physical properties by the rhythmic transformation and exchange of motions and tensions, which in their totality are defined as "exchange of force." We have thus a considerable number of more or less complicated processes to deal with, and it is necessary to examine some of them more in detail.

In the important organic process, known as the exchange of matter of the living substance, certain matters are taken up and

decomposed by the protoplasm, the resulting substances being partly ejected and partly assimilated. To effect this process, certain properties of the living substance, as well as certain conditions of the external circumstances, are absolutely necessary. The principal of these conditions is that the living substance must be surrounded by a liquid of an aqueous character, as the living substance can thrive in no other fluid (alcohol, ether, oil, &c.). On the other hand, pure distilled water is totally unfit for this purpose, for the following reasons :—

1. Chemically pure water deprives the living substance of certain constituents, for instance, salts, which are necessary for its activity.

2. It causes such a high degree of imbibition as to injure the mechanism of the regulating apparatus on which the rhythmus of the vital activity depends, and solid substances, necessary for the proper working of the vital functions, become dissolved.

3. Chemically pure water is devoid of certain substances (to be mentioned later on) which are necessary for the vitality of the protoplasm.

For all these reasons we must regard distilled water as injurious in its effects on the living substance. Among the matters which water must hold, in order to maintain the vital functions of an organism, the most important is free oxygen, as the living protoplasm dies, after a very short time, in water which does not contain oxygen. This becomes intelligible if we remember that all vital functions are due to oxidation processes which take place in the interior of the living substance. Just as a fire goes out unless supplied with air containing oxygen, so the living protoplasm must die without a constant supply of this gas.

Secondly, a certain amount of common salt is necessary, as it renders the water "indifferent" ; and the same is the case when other neutral sodium salts are added. This explains why all juices of the body, necessary for the nutrition of the tissues, contain these salts.

One of the most important factors, not only for life in general, but especially for the various vital functions in the different tissues, as well as for the vital energy, is a certain degree of imbibition which characterizes all kinds of protoplasm. Every piece of

protoplasm has its own mechanism, on the integrity of which its rhythmic functions depend; and one part of this mechanism is a certain *volume* of the plasma piece in question. So soon as, on account of a higher degree of imbibition, this volume exceeds a certain limit, the mechanism is damaged. The liquid surrounding the protoplasm must therefore be composed in such a way that the imbibition cannot become too great, a property which is called *indifference* by physiologists. Only such liquids as are in harmony with all these conditions should be allowed to penetrate to the protoplasm. In addition to the salts above mentioned, the surrounding liquid must contain further solid matters in solution, viz., *nutritive substances.* Life is a process in which the living substance continually produces energy, in the form of free motions and substantial secretions, without a corresponding diminution of the substance itself; but nothing produces nothing, and consequently the production of this energy requires a continuous supply of nutritive matters. The necessity of this uninterrupted supply will be made still clearer by regarding the subject from another point of view.

1. The oxygen which is taken up by the protoplasm from the surrounding medium produces an oxidative destruction of the formative substances of the tissues, and this loss must be replaced.

2. The protoplasm requires a certain amount of protection against the destructive effect of the oxygen; and this protection is obtained by the addition of such compounds as can be oxidized more easily than the formative substances of the tissues, thereby neutralizing, to some extent, the influence of the oxygen. Consequently, these compounds are properly described as *fuel substances.*

3. The process of secretion removes from the body, not only the products of decomposition of the substances mentioned under 1 and 2, but also certain other substances, especially salts. The loss of the salts must be made good, because they are essential to the maintenance of the requisite imbibition-mixture of the protoplasm, and of the mechanical and chemical equilibrium.

Among these nutritive substances, albuminates and albuminoids, as well as carbo-hydrates and neutral fats, with their soaps, are the most important. Of salts, I have already mentioned common salt

and other sodium salts, and to these must be added another important group, which I may describe as *nutritive salts*, the element of most consequence being potassium salts. A further group of substances which the surrounding medium should always contain are certain specific matters acting as chemical stimulants. They are of great importance, and I define them as odorous and savorous matters (matters which can be smelled and tasted). I have fully dealt with these characteristic compounds of animal life in chapter VIII.

Having now explained what substances the liquid surrounding the protoplasm must contain, if animal life is to be sustained, I will describe the substances which the liquid should *not* contain. As the number of matters injurious to the living substance is very great, I can only mention the two most important groups.

1. The surrounding liquid should contain no excretion-matters, or only very small quantities, as these, when remaining in the body, become actually poisonous. The principal excretion-matters are carbonic acid, various organic acids, acid salts, and compounds containing nitrogen (especially urea). So soon as any of these materials accumulate in the nutritive liquid, the vital energy diminishes and ultimately ceases altogether.

2. The liquid must be free from certain organic or inorganic substances which, owing to their injurious influence on protoplasm, are called *poisons*. There are a great many of them, as is well known, and it would lead too far to describe their properties and effects in detail.

Until now we have only dealt with the chemical part of the question, but there are also some important physical considerations, viz. :—

1. The surrounding liquid must have a certain temperature, which, in the case of the warm-blooded animals, is limited within a fixed number of degrees. Experiments show that a warm-blooded animal will die when its internal temperature has fallen as low as 59° F., and when it has risen above 113° F. As regards the human body, the *optimum* of temperature is 98·6° F., as estimated by the clinical thermometer ; this, in the normal state of health, is the temperature of the whole body, except that certain parts of the surface are somewhat cooler when exposed to the direct influence of cold air.

2. The liquid must be subject to a certain amount of pressure, in order to retain the necessary quantity of oxygen. For this reason animal life cannot exist beyond a certain elevation above sea level; and all endeavours to cross this limit have proved dangerous, or even fatal.

3. The motions of the surrounding liquid are of great importance. When the liquid is absolutely motionless, animal life is impossible, for the following reasons: (*a*) Because the chemical compounds produced by the protoplasm in its interior, and given off by it, cannot be removed by mere diffusion without the surrounding liquid being in motion. (*b*) Because the protoplasm requires to take up oxygen from the surrounding medium, and if this is motionless the supply of oxygen must cease. (*c*) Because the living substance gradually absorbs the nutritive matters in the liquid, and these cannot be supplemented by mere diffusion, but only by an adequate motion of the liquid. For all these reasons it is evident that fresh liquid must periodically come into contact with the living substance. The manner in which this can be effected is twofold: either the protoplasm is at rest and the surrounding medium in motion, or *vice-versâ*.

Summing up, we see that the vitality of the living substance is maintained by continuous contact with the aqueous fluids surrounding it, these fluids containing and providing the nutritive materials of the living substance, and at the same time removing the excretion matters, which may either be gases or solid compounds in solution. The gaseous exchange of matter is called *breathing*, and is more precisely tissue-breathing (as distinguished from blood-breathing and respiration). The exchange of solid compounds is effected by the processes of nutrition and secretion.

These processes can only be understood after we have studied the general laws and conditions under which substances are exchanged. The most important are the *laws of diffusion*; they are the result of the general attraction which all substances exercise upon one another, and may be explained thus:—

1. Two fluids (liquid or gaseous) will permeate each other, provided that they are miscible, without the assistance of chemical affinity or mechanical shaking, the result being an absolutely homogeneous mixture of both fluids.

2. If we have to deal with a liquid and a solid body, two cases are possible: (*a*) The adhesion of the molecules of the liquid to those of the solid substance surpasses the cohesion by which the molecules of the solid substance are held together. In this case the solid body diffuses into the liquid, *i.e.*, it is dissolved. (*b*) If a solid substance, not soluble in the liquid, is in question, two cases must be distinguished, viz., either they are totally indifferent to each other, or the liquid permeates the interstices of the molecules of the solid body, whereby the volume of the latter is increased, *i.e.*, imbibition takes place.

We must now discuss these different kinds of diffusion more in detail, as they are of great importance to the exchange of matter in connection with organic life.

In the first case, that of ordinary diffusion, we have to make three distinctions. *(a)* If both fluids are in a liquid state, we speak of *hydro-diffusion*. *(b)* If one fluid is a liquid and the other a gas, we have to deal with *gas-absorption*, and, when the gas becomes free again, with *gas-exhalation*. *(c)* Finally, if a liquid changes its state of aggregation, becoming gaseous, we obtain *evaporation*. As regards gas-absorption we have to remember that every liquid is capable of absorbing certain quantities of various gases; and, provided that all other conditions are alike, these quantities differ greatly, according to the nature of the gas and of the liquid. Moreover, with the same two substances (gas and liquid), the absorbed quantity declines with the increase of temperature, and rises with the increase of pressure. If a liquid has absorbed a certain quantity of a gas, and the pressure and temperature are suddenly changed in such a way that, according to the first-mentioned law, only a smaller quantity of the gas can be absorbed, the surplus is expelled from the liquid, and we obtain gas-exhalation. Gas-absorption and gas-exhalation are of the utmost importance for the respiratory functions of the body; but tissue-breathing is subject to the law that two liquids which come into contact exchange the gases which they contain. The diffusion of liquids into gases is called evaporation, as explained above. The amount of this evaporation is equal for the same two substances (gas and liquid), provided that all other circumstances are alike. Moreover, it must be borne in mind that all

evaporation absorbs heat. The process of evaporation is of the utmost importance to the human body, which is affected by it almost continually, because the air surrounding us is not, as a rule, saturated with watery vapours. The so-called *colloid substances* are produced by an intermediate process between solution and imbibition, and include some of the most important organic compounds, *e.g.*, the albuminates, &c. These substances have not completely lost the cohesion of their molecules.

Diffusion of liquids in solid substances is termed *imbibition.* It is one of the most characteristic properties of all substances forming animal or vegetable tissues. Every substance of this kind is capable of imbibing a certain quantity of liquid. The quantity changes according to the natures of the liquid and of the substance; and it varies with the temperature, and with the degree and continuance of the desiccation to which the solid substance may have been subjected before the imbibition took place. Bodies capable of imbibition are at the same time hygroscopic, *i.e.*, they attract the watery vapour contained in the atmosphere; all animal substances are very hygroscopic. The simplest case of diffusion is that of aqueous solutions in water; the rapidity of this process depends on the nature of the dissolved substances. There is a very important difference in this respect between the colloid and crystalloid substances, as the latter have a much greater rapidity of diffusion than the former. As regards hydro-diffusion, the process of osmotic action is one of the characteristic features of the vital functions. We understand by this process the diffusion of two solutions or liquids separated from each other by a membrane. The principal conditions for osmotic action are as follows:—*(a)* The liquids must be different. *(b)* They must be capable of imbibition by the membrane. *(c)* It is necessary for the osmotic action of a dissolved substance that the liquid on the other side of the membrane be likewise capable of dissolving the substance, and that it attract the latter; also that the molecules of the substance be not larger than the pores of the membrane. *Traube* is the discoverer of an important law in connection with these facts. He has found that the pores of a membrane are always somewhat smaller than the molecules of the substance of

which the membrane consists, and that the size of the molecule of a body is in direct proportion to its atomic weight. Consequently, no substance with the same, or a higher, atomic weight than that of the membrane substance itself can diffuse through the membrane. Moreover, a membrane-forming substance cannot diffuse through its own membrane. Finally, the smaller the molecules of a substance, the more easily it diffuses through the same membrane. As the animal membrane consists of colloid compounds, it is evident that colloid solutions diffuse with great difficulty, or not at all, through them, while the low-atomic crystalloid substances diffuse much more easily. The process, called dialysis, by which these two kinds of substances are separated, is based on this fact.

The osmotic properties play a very prominent part in the exchange of matter of the organisms. Many animal membranes are also provided with large-sized structural pores, enabling them to exercise the function of filtration; the quantity of the liquids which may filter through is increased by a greater difference of the tension or pressure, as well as by a greater porosity of the membrane.

After these explanations, we are in a position to investigate the exchange of matter of the living substance. I will commence with the function of breathing. Oxygen is the principal gas absorbed by the living substance. According to the laws of gas-absorption, the oxygen penetrates to the protoplasm; and in proportion as it is there used up for oxydation purposes, a fresh supply of oxygen is added. But this is only partly the reason of the absorption of oxygen by the living substance. A much more potent factor is the attraction which the living substance exercises on free oxygen, independently of the ordinary laws of absorption. The red blood corpuscules possess this attraction in a high degree, and they absorb the oxygen of the air which is drawn into the body by the process of breathing. But the tissue-substances have a still greater attraction for this gas than the red blood-corpuscules, and they therefore deprive the latter of their oxygen, and use it for their own purposes. In this case, however, the oxygen is not completely used up, but a portion of it is stored in the tissues. In great contrast to the activity of the living substance, with respect to oxygen, is its absolute *passivity* towards another important

gas, viz., carbonic acid. The consequence of this passivity is that the above-explained laws of gas-diffusion come into play. As the living substance constantly produces carbonic acid, it is evident that the latter is always given off to the surrounding media, provided that the pressure of the carbonic acid in the media is less than in the living substance.

As regards the other excretions of the body, we find that all substances which are expelled from the protoplasm are liable, unless promptly removed, to weaken its vital energy. In this respect we must first mention the acids and acid alkalis which are the products of the physical energy of the protoplasm. These substances are the so-called *fatigue-products*. With reference to the exchange of matter, the protoplasm shows two different conditions, viz., that of saturation, in which it neither absorbs nor excretes anything; and the condition of hunger, in which it easily absorbs, and again excretes, the substances which it requires. Moreover, we see that the exchange of matter is a rhythmic process, as it oscillates periodically between the states of saturation and of hunger The reason that the protoplasm does not remain permanently in the state of inactivity and saturation is probably the following :—Protoplasm consists of a number of chemical compounds which can be easily oxidized, and its capacity to absorb oxygen is, as we have seen, very great. At the same time, it is always under the influence of chemical and physical stimulants which favour oxidation. This commences as soon as a sufficient quantity of free oxygen is stored up, provided that the protoplasm contains no substances (*e.g.*, fatigue-products) which can interfere with the action of the oxygen. When the protoplasm is in a state of saturation and inactivity, no oxygen is taken up by it, while the living substance continually stores up quantities of this gas. So soon as the process of storing up has reached the degree necessary to cause vital Irritability, the protoplasm becomes active. The result is threefold. (1) Oxygen is consumed. (2) Free, active energy is produced. (3) Fatigue-products are created. Under the influence of the last-named, the vital irritability gradually ceases to exert its influence, and the protoplasm relapses into its previous state of inactivity, which, however, is not now a condition of saturation, but one of hunger. During this state a

new exchange of matter with the surrounding medium takes place, with the result that fresh nutritious substances in solution are taken up, and that the fatigue-products are excreted.

The protoplasm then returns to its original state of saturation and rest, as above explained, and the rhythmic circle commences again.

This peculiar rhythmic exchange of matter is principally due to the great lability of the chemical and physical equilibrium of the protoplasm, and to its property of absorbing free oxygen. As soon as the storing up of this gas has reached a certain degree, the chemical equilibrium is disturbed, with the consequence that the physical equilibrium is also upset, *i.e.*, the elasticity of the solid parts of the protoplasm is diminished, and the equilibrium of diffusion and filtration between the living substance and the surrounding medium is disturbed. The *chemical* cause of the exchange of matter is therefore oxygen, and the *physical* cause is the vital irritability of the protoplasm.

## XVI.—THE SOURCE OF THE VITAL FORCES.
(1878.)

AMONG the solid substances which a liquid suitable for the nutrition of the protoplasm must contain, albuminous compounds, sugars, and fats are of chief importance. If we examine the chemical composition of these substances, we find that their molecules contain very little oxygen. Consequently, the atomic contact is maintained merely by the weak affinities of carbon on the one side, and of hydrogen or nitrogen on the other. It is well known that vital energy is always developed when a weak chemical affinity is replaced by a strong one. Therefore, if the fats which have penetrated the living substance are burned (carbonic acid and water resulting), a considerable amount of vital energy must necessarily result. Experiments indubitably prove that this process of combustion actually takes place; and the same may be said of the different kinds of sugar, as well as of the albuminous substances. In the case of the latter, which contain nitrogen, urea is obtained, as well as carbonic acid and water. If we try to compute the quantity of vital energy produced in the human body by means of the normal quantity of food consumed, we obtain the remarkable figures of 2·3 to 2·7 millions of units of heat for each day (1 unit equal to the quantity of heat required to raise the temperature of 1 gramme of distilled water by 1 degree centigrade). As 1 unit of heat corresponds to the mechanical work of 424 grammemeters, we find that the above figures correspond to a sum of mechanical energy by means of which a man, of the average weight of 75 kilogrammes, can be raised to an altitude of not less than 15,333 meters, *i.e.*, to twice the height of the loftiest mountains on the globe. It is assumed in this computation that all heat of combustion is obtained as mechanical energy, which is of course an impossibility, because the greater part of it is given off as heat to the surrounding atmosphere, by means of conductivity, radiation, and evaporation.

In order to ascertain how far the human working-capacity depends upon this combustion-process of the substances of nutrition, two kinds of experiments have been made. (1) The normal quantity of food actually consumed in a day has been computed; (2) this quantity has been directly ascertained by measuring the mechanical amount of work which is done in a day, as well as the amount of heat given off to the surrounding air. The results of measurement and of computation coincide so nearly that the assumption of the old physiological schools respecting the special character and cause of human vitality has been found altogether incorrect.

After these facts had been established, several investigators tried to determine the part which each of the three groups of substances (albuminates, sugar, and fats) plays, with reference to the production of energy. This question is of great practical importance, as it is in close connection with the problem of the nutrition of the human body. Detailed investigations by our best authorities have established the following results:—All three groups of compounds assist in producing the vital energy of the living substances, but they differ as regards intensity and degree. These differences are principally quantitative. It has been proved experimentally that so soon as the energy of the living substance is increased, the consumption of substances without nitrogen (sugar and fat) becomes greater, while the comsumption of albuminous substances remains almost the same. The only explanation of this is, that fats and sugar are consumed on account of their possessing a much higher degree of oxidability than the albuminous substances. The part which the albuminous substances play in connection with the vital energy of the body is of diverse nature. (1) They provide the living substance with oxygen, because it is proved by experiment that the storing of this gas in the tissues is mainly due to the albuminous substances. (2) It depends on the quantity of albumen present how much mechanical energy can be produced, for the tensions and pressures of the living substance originate in the solid parts of the latter, which consist of albuminous substances. The following simile will explain this more fully:—If we ignite gunpowder in the open air, very little mechanical energy is obtained, as it burns off quietly,

and only produces a certain amount of heat. But if the ignition takes place in the interior of a gun, a large amount of energy becomes free, and acts as a mechanical force. Therefore, the more albuminous compounds the living substance contains, the greater will be the amount of mechanical energy.

It is important to add to these explanations a few more remarks on the ultimate causes of vital energy. All nutritive matters which produce energy owe their origin to the powers of assimilation of the plants. These, as a rule, absorb carbonic acid, water, and ammonia, three compounds in which the strongest affinities exist between carbon, hydrogen, oxygen, and nitrogen. It is the physiological task of the plant to rid itself of these strong affinities, and to replace them by weaker affinities, as, for instance, those between carbon and hydrogen, or between carbon and nitrogen. The plant effects this by withdrawing oxygen from water and carbonic acid, leaving the remaining hydrogen and carbon to form carbo-hydrates with free affinities. These come into contact with other atomic groups; and wherever this process is gradually continued, we obtain more or less complicated substances, possessing gradually less oxygen, viz., first the well-known plant acids, then the fatty acids, and finally the neutral fats and the carbohydrates (starch, sugar, and woody substance). As regards the formation of the albuminous substances, our researches are not yet complete, but we know that their starting point is ammonia, and that in this case also the weak affinity between nitrogen and carbon is substituted for the strong affinity between nitrogen and hydrogen. But this substitution of weak for strong affinities requires a certain amount of energy, *i.e.*, free forces come into play, which disappear again in the course of the process. These are by no means internal forces of plant-life, but are directly derived from *sunlight*, which is, so to speak, absorbed by the green parts of the plant. It is often stated that coal, wood, mineral oil, in short, all our fuel materials, are merely "condensed sunlight," and we may say the same as regards our food supply. Thus we arrive at the conclusion that the vital energy of human life is solely due to the influence of that great generator of heat and life, *the sun.*

## XVII.—TRAINING AND EXERCISING.

(1878.)

EVERYBODY knows that "practice maketh perfect," *i.e.*, that it is the chief cause of capability to perform certain specific kinds of work. The scientific importance of this fact has not been sufficiently recognized or investigated. Exercising and training are very complicated processes; we have to deal not only with their influence on the various tissues and other parts of the body, but also with the co-operation of these various parts. We must first define what exercising actually is; we do not understand by it every kind of activity, but only the frequent repetition of a certain amount of work performed in the same way, without reaching a limit which we call overwork.

Exercising strengthens the organism, which may be ruined by overwork, and I therefore define it as a certain amount of work, producing particular effects, which I proceed to describe. The first effect consists in exchange of substance as regards the chemical and physical composition of the tissues and other organs, leading to variations in the corresponding functions. To mention the more general features—we distinguish a trained from an untrained organ by their respective dimensions; the trained organ is relatively the larger of the two, and possesses more active tissue parts than the untrained one. This especially refers to the albuminous substances; water is inactive, and the stored-up fatty substances are only indirectly active; the trained parts of an organism are therefore richer in albuminous substances, and poorer in fatty substances and water, than the untrained. Physically, the trained parts are distinguished from the untrained by higher specific gravity. Muscles show the greatest difference in this respect, as is evident when we compare corresponding muscles of wild and of domesticated animals, or muscles which are often

used, with such as are only occasionally employed. Trained muscles are darker in colour, and their fibres are coarser and tougher, compared with untrained muscles, involving, of necessity, a higher specific gravity.

As regards the functions of the muscles, the most striking effect of exercising and training is an increase of energy and velocity. In which way this increase of energy and velocity is shared, when we have to deal with the contractions of a muscle, has not yet been experimentally examined; but it is probable that the contraction takes place in all parts of the muscle at the same time. As regards the increase of *force* in muscles, under the influence of training, we have not yet sufficient experimental material in hand to speak positively; but the greater hardness of the muscles, in connection with the above-mentioned increase of the albuminous substances, appears to be in direct connection with the larger cross-sections observed in trained muscles. The third functional effect of training consists in a prompter regulation of the activity and energy of the muscles, *i.e.*, the influence of the will is greater, and acts more promptly as regards force, velocity, and quantity. This empirical fact is principally due to a better developed regulation of the irritability of the nerves. The fourth effect of exercising and training is an increased consistency of the muscle-fibre, and it is questionable whether this is due to a change in the muscle-fibre, or to some other cause. However that may be, we observe an alteration in the amount of energy required for the removal of the fatigue-products. Moreover, the consistency of well-trained muscle-fibres is likely to be greater, as they have at their disposal more substances capable of producing energy (*inogenous substances*); and the physical properties of trained muscles, especially the smaller amount of water which they contain, point in this direction. The fifth effect of training consists in the greater independence of the various muscles. While untrained muscles easily communicate their mobility and irritability to other muscles, whose co-operation is neither voluntary nor of practical advantage, trained muscles are much less apt to do so. This is partly due to the better isolation of the conductivity of the nerves, and partly to the better isolation of the different muscles themselves.

Coming now to the *passive* parts of the motoric system, and to the effect which exercising and training have upon them, we find that the longitudinal growth of the bones is stimulated, and that this growth is accompanied by increased functional velocity and energy. For example, a person with long legs can, *cæteris paribus*, run faster than an individual with short legs. A further effect of exercise is the considerably enhanced development of those projections of the bones whence the sinews originate. The advantage is evident, viz., the more these projections are raised above the surface of the bones, the greater will be the power of motion of the sinews. Further, well-exercised bones are notoriously firmer, tougher, and stronger than bones which are rarely exercised, as the latter usually contain much more water than the former.* Moreover, if we compare an animal's joints which are in constant use, with joints which are used less frequently, we observe the following important differences. The contrast between the soft parts of the capsules, and between the exterior ligaments, is apparent. In the former case the ligaments are stronger, and the softer parts are more flexible, causing increased mobility and firmness of the joints. That we are fully justified in regarding this as a direct result of exercise is proved by many observations. The effect is twofold: First, the mobility of a joint greatly decreases if the joint be not used for some time, as, *e.g.*, when a bone is fractured. Second, the mobility increases in direct proportion with use and exercise. The effect of training is also shown in the development of the sinews, which, in well-trained muscles, are much more separated from the muscular substance than in untrained muscles. The tissues, too, are firmer, and the elasticity is greater. It must be regarded as a favourable effect of training on the strength and velocity of the motive power of the body, when less resistance is offered by the softer parts near to the muscles in question, as by every contraction of the latter their cross-sections are increased, displacing the neighbouring softer parts. I have repeatedly explained that the fatty substances of the body are obstacles to velocity of movement; and if, therefore, through energetic training, the body loses part of its fat, this is a distinct advantage for the contractibility of the muscles.

* Compare chapter XVIII.

Turning now to the *nervous system*, we have again to lament that experimental physiology teaches so little respecting the physiological effects of exercising and training.* It is not, however, difficult to ascertain that the central nervous organs are more developed in animals of a lively nature than in sluggish animals. The articulate animals are very instructive in this respect, as insects, crustaceæ, and spiders have their nerve centres in the more active parts of the body (head and thorax). These nerve centres are much more developed than those which have to do less work, *e.g.*, the abdomen in insects and spiders; while crayfish, caterpillars, and so on, whose working energy is more equally divided over the whole body, show no such differences. As regards *man*, it is certain that individuals who are intellectually active have a better developed brain, with a greater number of windings, than those who are only bodily active.

*Meynert's* comparative investigations on the brains of bats and kangaroos illustrate this fact, so far as mammals generally are concerned. He has found that so soon as a part of the body is frequently used, the corresponding nerve centre of the brain increases in quantity. In this connection I may mention the fact that, as regards birds and mammals, the small and lively species possess, comparatively speaking, more brains than the large and sluggish birds. If we translate these physiological changes into the language of daily life, we may say that, by exercising, man not only becomes better trained, but also more accurate and diligent.

*Co-ordination*, so-called, forms quite a different factor in connection with the activity of the nervous system. Even the simplest acts of a human being are the result of the co-operation of a number of various muscles, or groups of muscles, which are more or less independent of one another. The co-operation of these different elements is, as observation of a young child will show,† by no means inborn; a separate act of will is required for *every* motion of a muscle or group of muscles, while we find that the motions of the muscles of an adult are all conducted by a single act of will. All co-ordinated actions are characterized by the fact that their execution is effected without the special attention of the

* Compare in this respect Dr. Jaeger's further discoveries. See chapter XVIII.

† Compare chapter XXVII.

mind. As regards the effort of the will in most of our customary actions, I remark that not only is a single impetus sufficient to produce a complicated action, but also that a lesser impetus is required when we have to deal with actions to which the body has been trained. In harmony with this is the fact that customary actions react more quickly on a given incentive.

These observations show a higher motoric capacity of the nerves, under the influence of custom and training. The highest degree is reached when a customary action is almost involuntary ; and thus we see that training and exercising lead back to the so-called reflex movements of the animals.

A further important difference exists between deliberate actions and those which have become customary by training. We find that, under the influence of training, various acts may be performed at the same time, although this is impossible so long as each act requires the special attention of the will. But it is easy to combine deliberate actions with customary ones, and in our daily life we frequently find that this is done. It is interesting to note how this combination takes place. As long as an action requires attention, a second action cannot be performed at the same time. But so soon as an action has become customary, a second which requires attention may be added to it simultaneously ; and when this has become customary, a third action requiring attention may be added, and so on. Many of our more complicated actions might be cited to prove this ; but the facts are so well known that they need no special illustration. It is a question of practical importance to ascertain which actions can reach the highest degree of accustomed accuracy. The answer is, that only *the most useful actions* can reach the highest degree, because in such cases alone can the factor of deliberation be completely absent.

So far, we have investigated the effects which exercising and training have upon single actions. But now we must also consider to what extent training influences the whole body. So long as an action requires deliberation, it excludes, as we have seen, for the time, all others in which deliberation is necessary ; therefore, the more varied the sphere of activity of an organic being, the more often are its actions interrupted, and the less time is at the disposal of the organism to become accustomed to certain specific actions.

In connection with this fact I must mention the highly important problem of *instinct*, which has already been discussed by *Darwin* and others. In our daily life we frequently confuse instinct and custom ; but the fundamental difference between the two is that every customary action is a product of training, while every instinctive action is the product of an inherited disposition. As regards the latter, we have to deal with a greater irritability of certain nerves, as well as with an inherited anatomical connection between particular nerve centres ; but it is evident that in the course of time every instinctive action of an organism may become a customary one.

## XVIII.—THE SPECIFIC GRAVITY OF THE BODY.

(1878.)

AMONG the many problems upon which the Darwinian theory has shed new light, hardly any is of greater scientific, and at the same time practical, interest than the question of the effects upon the body of *use* and *exercise*. *Darwin* is not the first who has tried to find a scientific explanation of this problem, as *Lamarck* had already recognised its great importance in connection with the development of animals. I first approached this subject by examining the influence of use and exercise on the human skeleton, and I found the growth of the bones of the human skeleton to be affected in a high degree by use and exercise. The conclusions at which I arrived showed me that this is not only a theoretical question, but one of great practical moment from the hygienical, as well as from the educational, point of view. Recognising this, I set to work to also investigate the physiological side of the problem. *Helmholtz*, *Hankel* and others had just published their interesting experiments and researches on the velocity of the voluntary motions of the nerves. When I saw that this velocity is not a constant factor, but one which is subject to the same variability which influences the whole organic nature, I came to the conclusion that methodical use and exercise must have a great influence upon it. This variability is the reason why the above-named investigators were unable to obtain results which coincided. As soon as I had ascertained that we have by no means unchangeable values before us, but that everything in connection with use and exercise is variable in the sense of the Darwinian theory, I became convinced that the practical side of the question is still more important than the theoretical, and I determined to extend my researches in the practical direction. By the assistance of some officers of the German army I was enabled

to make a large number of experiments with soldiers, which clearly proved the great influence which exercise and training have on the general condition of the human body.

In the first place, the soldiers whom I examined showed that the longer they had served with the colours the *greater was their specific gravity*.

A second point which I found to be of high practical value is in regard to the functions of *breathing*. I used an instrument called a spirometer to ascertain the capacity of the lungs; and I soon became convinced that exercise and training affect the capacity of the lungs and the functions of breathing in a much greater degree than I had anticipated. Having thus found that the theory of constant functions had to yield to the doctrine of variability, I concluded that the correctness of these observations might best be tested by experiments with gymnastic exercise. A number of such experiments gave striking confirmation in this respect, as, after a very short time, the capacity of breathing and the mobility of the thorax became much greater.

*Beneke's* classical researches on the pathological effect of the changes of matter, and *Ranke's* studies on the motoric conditions of nerve fibres, convinced me *that the amount of water in the tissues, and, in connection therewith, the increase or decrease of the specific gravity of the body*, is a question of great physiological and hygienic moment. No doubt, everything in connection with the accumulation of fat in the body must be considered injurious to health; and up to the time of my above-mentioned discoveries I was under the impression that fat is the principal offender in the body. But now I think differently, as I have found that the amount of tissue-water is of great importance in this respect. The less the amount of water, the greater is the specific gravity; and the motoric conditions improve in proportion to the greater specific gravity. This explains why energetic bodily exercise is such an important hygienic factor, viz., it enhances the evaporation of the body, reducing the amount of water in the tissues; and the more the body loses of its tissue-water the greater is its resistance to pathological influences. Consequently, the sanitary influence of energetic exercise and gymnastics is due to the decrease of tissue-water in the body.

After having ascertained this, I at once recognised the correctness of the two well-known popular definitions which speak of the "*softening*" and of the "*hardening*" of the body. Hardening, as usually defined, is the capability of the human body to resist those external influences which are popularly assumed to be the causes of many diseases. The hardening of the tissues is identical with the loss of tissue-water. The softening of the tissues, on the other hand, involves the decrease of the specific gravity ; the body becomes less firm, and the proportion of the more liquid substances (water and fat) increases, compared with the amount of the more solid substances (albuminates and albuminoids). From what I have explained, we are now in a position to express these conditions arithmetically, viz., by measuring the increase or decrease of the specific gravity of the body.

Hitherto no scientific definition of "hardening" and "softening" could be given, except the unsatisfactory statement that "hardening" is the physiological faculty of accustoming the body to cold. But one thing has been observed by physicians and physiologists, viz., that, in connection with contracting a chill, the lowering of the surface temperature of the body produces a contraction of the capillary vessels of the skin, which thus become more or less bloodless. In the case of a "hardened" body, a prompt reaction takes place immediately after the influence of the cold temperature has made itself felt, with the effect that the blood rushes again to the skin ; while, when the body is in a softened condition, the capillary vessels of the skin remain inactive for a much longer time.

Generally speaking, we may say that the greater the amount of tissue-water the less the resistance to disease. What is called the "softening" process is nothing else than an accumulation of water in the tissues, properly termed *hydrostasia chronica*.

The great practical importance of this matter is best shown by the following figures, representing the average specific gravity of soldiers :—

AVERAGE WEIGHT OF EVERY 1,000 CUBIC CENTIMETRES.

| | | | | | |
|---|---|---|---|---|---|
| 843·7 | grammes | for soldiers | during the | 1st year | of service. |
| 917·1 | " | " | " | 2nd " | " |
| 947·4 | " | " | " | 3rd " | " |

This means an increase of the average specific gravity of not less than 12·3 per cent. between the first and the third years of service.

Of course the quantitative proportions of bones, muscles, blood, and various other items must be carefully studied, because it is clear that if two men, one slender and the other robust, have exactly the same specific gravity, the body of the robust man is in a better hygienic condition than that of the slender one. Five different factors have to be considered in this respect, viz.: air, water, fatty substances, salts, and albuminous compounds. We will first consider the influence of air. The functions of two organs—the lungs and the intestines—are in close relation with air and gases. I have computed that the maximum influence which the quantities of air in these organs may have on the specific gravity of the body is much too small to explain the great differences in the above figures, which can therefore only be due to changes in the constituents of the tissues of the body. Among these constituents the fatty substances have the lightest specific weight, viz., 0·937 ; but even if we base our calculations on the maximum amount of fatty substances (including the molecular fat contained in the living protoplasm), we find that this factor does not explain the great differences indicated by our table. Thus there can be no doubt that these differences in the specific gravities are mainly due to changes in the three remaining constituents of the tissues, viz., salts, albuminous substances, and water. Therefore, the specific gravity is raised by a decrease in the amount of water. *Beneke* has made some very interesting experiments in this respect, by analyzing a number of arm-bones of different persons. The following table contains the principal results of these experiments :—

| | Soldier. | Woman affected with Phthisis. | Boy who died of Caries. |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Water ... ... ... | 13·6 | 38·8 | 63·4 |
| Salts ... ... ... | 38·0 | 27·5 | 16·4 |
| Organic Substance ... | 22·0 | 21·4 | 20·2 |
| Fat ... ... ... | 26·3 | 12·2 | |

Another striking proof in favour of my contention has been furnished by *Ranke*, who has compared the relative quantities of blood, brain, muscles, and spinal marrow of different individuals, and has found the great differences shown in the following table :—

| | Young, healthy criminal (beheaded). | Old man who died of Marasmus. | Difference. |
|---|---|---|---|
| | Solid Substances. Per cent. | Solid Substances. Per cent. | Per cent. |
| Muscles ... ... ... | 24·3 | 15·2 | 37·4 |
| Brain ... ... ... | 25·0 | 19·5 | 22·0 |
| Spinal Marrow ... ... | 30·3 | 27·1 | 10·5 |
| Blood ... ... ... | 21·0 | 11·0 | 47·6 |

Two explanations of these facts are possible, viz., we may describe the increase of specific gravity either as a dehydration, or as an augmentation of the solid substances. The result is the same, viz., *a concentration of the living tissue-substance.*

I have mentioned already that, by the kindness of the Prussian and Würtembergian War Offices, I was enabled to examine a great number of statistical tables on the mortality of soldiers. These tables comprise a period of more than six years before and after the Franco-German war. I naturally concluded that if a causal connection exists between specific weight and inclination to disease, this relation must make itself noticeable *by a decrease in the mortality of soldiers* during the latter part of their service with the colours; and this is actually the case. The statistical tables at my disposal comprise the following periods: First, the years 1867, 1868 and 1869, and the first half-year of 1870. Then

follows an interval of a year, owing to the Franco-German war, and the statistics commence again with the second half-year of 1871. Finally, the statistics comprise the years 1872 and 1873 and the first quarter of 1874. We see that the material before us is very large, and therefore great accuracy may be claimed for the results arrived at.

As this is a most important matter, some of the tables are given in detail. I have selected typhoid fever as a frequent and characteristic disease. The tables are arranged under two headings: the first contains the *figures* of the three years of service, all figures being computed for the same number of individuals who served during the first year, as during the second and third years many German soldiers are discharged on leave of absence. Consequently, this method of computation is necessary for the sake of comparison. The second heading gives *the proportions* of the three years of service, compared with one another, the mortality figures of the second year being taken as 100.

The negative differences of the third year are expressed by the minus sign (—), and the positive difference of the first year by the plus sign (+). By this arrangement we obtain a clear insight into the actual conditions existing.

If we first examine the mortality figures of Table I., we observe that the mortality during the first year of service is 56·6 per cent. higher than in the second year. This, of course, is due to various abnormal causes:—

1. The weak men, who have somehow passed the medical examination of recruits, are weeded out during the first year, and the mortality is increased accordingly.

2. The decided change in the mode of living, when a man enters the army, not infrequently has an injurious effect upon the health; and is also instrumental in increasing the mortality figures.

3. The hard work gives rise, during the first year, to a number of ailments which are unknown to the trained soldiers of the second and third year.

These factors must be considered; but there is a further very potent influence, as the following will show.

We notice another remarkable reduction (48·6 per cent.) of mortality in the third year of service, as compared with the second. This reduction is neither due to the weeding-out process, nor to any of the other factors mentioned. On the contrary, it is well known that the soldiers who are discharged at the end of the second year are sound in every respect, and thoroughly efficient; so that, without these discharges, the third year's figures of mortality would doubtless show a still greater reduction. Cases of *consumption* may also be taken as indicating the weaker elements in the army, not only because of the nature of this disease, but also on account of the high figures of mortality; and we find the characteristic fact that the mortality due to consumption is only 5·6 per cent. higher during the first year than during the second year, and 13 per cent. lower during the third year.

For these reasons I am of opinion that the mortality during the first year is greatly influenced by the factor to which the reduction of mortality is due during the second and third years, viz., the gradual increase of immunity produced by the military training. No other explanation can be brought forward for the striking difference between the mortality figures of the second and third years. In strict accordance with this, we find that the diseases caused by chills and colds show a great reduction between the second and third years of service. But the most striking fact is that the mortality due to *infectious* diseases also shows an enormous reduction. As I have mentioned before, I have selected typhoid fever as one of the most common infectious diseases. The subjoined tables refer to the German army *in toto*, and to one of the best trained sections of it, viz., the Royal Prussian Guards.

Finally, the third table comprises the year 1869, as I thought it advisable to select a year before the Franco-German war, in order to exclude all possible contingencies produced by the influence of the war.

TABLE I.

*Mortality from Typhoid Fever in the German Army.*

| Years. | Computed for the same number of men. | | | Difference between 1st and 3rd, as compared with 2nd year of service. Percentage. | | |
|---|---|---|---|---|---|---|
| | 1st Year of Service | 2nd Year of Service. | 3rd Year of Service. | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. |
| 1867 ... ... ... | 201 | 162·5 | 72·0 | + 23 7 | 100 | — 55·7 |
| 1868 ... ... ... | 214 | 188·0 | 108·0 | + 13·8 | 100 | — 42·6 |
| 1869 ... ... ... | 174 | 102·2 | 73·0 | + 72·5 | 100 | — 28·6 |
| 1870 (1st half-year) | 68 | 49·0 | 25·3 | + 38·7 | 100 | — 48·4 |
| 1871 (2nd half-year) | 114 | 44·0 | 30·7 | + 159·0 | 100 | — 30·0 |
| 1872 ... ... ... | 296 | 99·0 | 32·0 | + 200·0 | 100 | — 67·7 |
| 1873 (1st quarter) . | 31 | 25·5 | 8·0 | + 21·5 | 100 | — 69·1 |
| 1873-1874 ... ... | 133 | 115·4 | 55·0 | + 15·2 | 100 | — 52·4 |
| Total ... ... | 1,231 | 785·9 | 404·0 | + 56·6 | 100 | — 48·6 |

TABLE II.

*Mortality from Typhoid Fever in the Royal Prussian Guards.*

| Years. | Computed for the same number of men. | | | Difference between 1st and 3rd, as compared with 2nd year of service. Percentage. | | |
|---|---|---|---|---|---|---|
| | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. |
| 1867 ... ... ... | 19 | 17·37 | 8·0 | + 9·3 | 100 | — 54·0 |
| 1868 ... ... ... | 4 | 21·46 | 21·0 | — 436·0 | 100 | — 2·2 |
| 1869 ... ... ... | 18 | 13·29 | 4·0 | + 35·4 | 100 | — 70·0 |
| 1870 ... ... ... | 2 | 8·17 | 0 | — 308·0 | 100 | — |
| 1871 ... ... ... | 8 | 4·08 | 1·33 | + 96·0 | 100 | — 67·4 |
| 1872 ... ... ... | 35 | 12·26 | 2·7 | + 185·0 | 100 | — 78·0 |
| Total ... ... | 86 | 76·65 | 37·0 | + 12·2 | 100 | — 51·8 |

TABLE III.

*Mortality from Typhoid Fever in different Army Corps in the Year* 1869.

| Army Corps. | Computed for the same number of men. | | | Difference between 1st and 3rd, as compared with 2nd year of service. Percentage. | | |
|---|---|---|---|---|---|---|
| | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. |
| Royal Prussian Guards | 18 | 13·28 | 4·0 | + 35·5 | 100 | — 69·0 |
| 1st Army Corps... | 32 | 5·11 | 0 | +526·0 | 100 | — |
| 2nd " " ... | 8 | 4·02 | 27·0 | + 99·0 | 100 | +571·0 |
| 3rd " " ... | 6 | 5·11 | 0 | + 17·4 | 100 | — |
| 4th " " ... | 8 | 11·24 | 2·7 | — 29·0 | 100 | — 76·0 |
| 5th " " ... | 15 | 11·24 | 1·33 | + 33·4 | 100 | — 88·0 |
| 6th " " ... | 19 | 17·37 | 4·0 | + 9·4 | 100 | — 77·0 |
| 7th " " ... | 8 | 3·06 | 6·7 | +161·0 | 100 | +119·0 |
| 8th " " ... | 12 | 4·08 | 4·0 | +194·0 | 100 | — 2·0 |
| 9th " " ... | 10 | 9·2 | 6·7 | + 8·7 | 100 | — 27·2 |
| 10th " " ... | 15 | 3·06 | 13·3 | +390·0 | 100 | +331·0 |
| 11th " " ... | 23 | 15·33 | 4·0 | + 50·0 | 100 | — 74·0 |
| Total ... ... | 174 | 102·2 | 73·0 | + 70·0 | 100 | — 28·6 |

## XIX.—PROFESSOR NAEGELI'S AND MY OWN RESEARCHES ON INFECTION.

(1878.)

SHORTLY after I had arrived at the conclusions given in the last chapter, I came across the latest work of my colleague, *Professor Naegeli*, on the Lower Fungi and their Relations to Diseases (1877); and I at once recognised that here was a complete explanation of the results of the experiments which I had made in this direction.

In connection with *Pettenkofer's* underground-water theory, *Professor Naegeli* came to the conclusion that the germs of infectious diseases belong to the same group of living organisms as the familiar ferments of putrescence; and he offers new and convincing proofs of the specifically organic nature of the germs of infection.

I must add that I do not agree in all respects with *Professor Naegeli's* views, as I think that he greatly under-estimates the part which water plays in transmitting infectious germs from one place to another. I have personally examined into this, in connection with a number of cases of typhoid infection, which were all transmitted by drinking water; and the sanitary reports of the German army (1873—1874) contain several striking cases in point.

But in other respects I heartily welcome *Professor Naegeli's* investigations on the vegetation of the lower fungi. Together with my own researches on the increase in the specific gravity, they form a complete theory on the causes of disease.

As *Naegeli's* views are of equal fundamental importance for this theory to my own, I must shortly review them, with reference to the question of immunity from disease. Seeing how *Naegeli* has forestalled me, I am surprised that he did not himself draw the final conclusion which I will presently set forth.

On the question of immunity *Naegeli* remarks :—

1. A certain amount of water is necessary for the growth and propagation of the lower fungi. Desiccation, however, does not

result in death, but in a latent state of life, during which the vital functions remain inactive. This latent state may last for a long time, and, under certain conditions, even for centuries.

2. In water containing no nutritive substances the fungi die of exhaustion after a comparatively short time.

3. All non-nutritive substances soluble in water, and nutritive substances when present in excessive quantities, are injurious to the fungi ; and if a certain degree of concentration of these substances is reached, the fermentation and growth of the fungi become impossible.

*Naegeli* further expresses his views on concentration, as follows :—Those substances soluble in water, which are not used as food, play an important part in the life of the fungi, as, with the exception of oxygen, they are obstacles to the growth of the fungi. Therefore, these substances may be regarded as poisonous to the fungi, their influence increasing with their relative quantity. The degree of influence, however, varies greatly, as very small quantities of some substances, and much larger quantities of others, are necessary to exercise a poisonous effect.

The fungi producing yeast-fermentation are characteristic in this respect, as their products of decomposition (those which are volatile excepted) prevent the propagation of the fungi themselves.

The consequence is, that in a solution where lactic or alcoholic fermentation takes place, the amount of lactic acid or of alcohol can only reach a certain degree ; because fermentation ceases unless the lactic acid is from time to time removed by means of calcium carbonate, or the alcohol by evaporation or by the formation of acetic acid.

I can support this important observation of *Naegeli* by a striking example. As a student, I made many osteological experiments ; and when macerating the objects, I found that if the vessels were closed so as to be air-tight, fermentation did not properly proceed unless fresh water was added. When, on the other hand, the liquid became too much diluted, fermentation also stopped. Hence, both too strong and too weak concentrations of the liquid prevent the growth of the fungi, as *Naegeli* has explained.

*Naegeli* further states that all nutritive substances become noxious to the fungi so soon as the substances have attained a certain degree of concentration. For instance, the fermentation process, and the growth of the lower fungi, can be interrupted by merely adding a certain amount of sugar to the liquid in which they grow. The same result takes place when the nutritive solution gradually dries up. For example, the nutritive substances in moist bread facilitate the growth of the fungi ; but as the bread dries, and the nutritive substances become more concentrated through the evaporation of the water, the activity of the different fungi gradually ceases.

The same observation may be made with meat. If we dry, or salt, or smoke meat, the nutritive liquid becomes too concentrated to allow the fungi to develop. The action of the fungi which attack the human organism is analogous, and I am able to supplement *Naegeli's* observations by stating the following law : an accurate knowledge of the effect which dehydration exercises on the lower fungi explains the effect of dehydration on the human body, and on the degree of immunity from infectious diseases.

It is astonishing that *Naegeli* did not draw this conclusion, considering how carefully he studied the problem in question. He further explains that one of the external conditions which greatly influence the vital functions of the lower fungi has hitherto been almost disregarded. This refers to the interference of fungi belonging to other groups under analogous conditions of existence, and here we have a similar ruthless struggle for existence as among the higher animals and plants.

A species of fungi, which flourishes when alone, is sometimes annihilated by another species, better adapted to grow and propagate under the special conditions of the case. This important factor in the problem has hitherto been overlooked, giving rise to many erroneous views, especially in connection with modern antiseptic treatment. For example :—If three different kinds of lower fungi, viz., yeast fungi, bacteria, and mildew fungi, are placed in a nutritive solution containing sugar, only the bacteria will propagate, producing lactic fermentation. But so soon as a little tartaric acid, not more than ½ per cent., is added to the same solution, the yeast fungi gain the upper hand, producing alcoholic fermentation.

Finally, if some more tartaric acid (about 4 or 5 per cent.) is added, the third kind, viz., the mildew fungi, will be in the ascendant. To conclude from these facts that the ½ per cent. of tartaric acid prevents the development of the bacteria would be wrong. When we use bacteria *alone* in the experiment they grow and multiply, even if as much as 1½ per cent. of tartaric acid is added to the nutritive solution. Hence, the above results must be due to the struggle for existence between the different kinds of fungi.

The action of the yeast fungi is characteristic, and shows that the advantage usually lies with those of the competitors which at the beginning of the struggle were superior in numbers; and it is by acting on this knowledge that the growth of the different kinds of fermentation is often regulated. The following experiment will confirm this. If exceedingly small quantities of bacteria and yeast fungi are placed in a neutral nutritive solution containing sugar, the bacteria will always multiply, and in most cases lactic acid is produced; the yeast fungi are either altogether destroyed at the outset of the struggle, or their overthrow becomes complete so soon as a trace of the first solution is added to a second nutritive solution, as then the fermentation is always that of bacteria. The result is quite different when the experiment is initiated with a somewhat larger quantity of yeast fungi, which, if superior in number, will be victorious over the bacteria; and if the experiment is repeated with three subsequent nutritive solutions, we ultimately obtain an absolutely pure cultivation of yeast fungi, producing alcoholic fermentation.

*Naegeli* explains the relations between the germs of infection and the human organism by stating that the fungi cause, and are not merely accessory to, the infectious diseases. If certain lower fungi find their way into the human body, a struggle for existence commences between these fungi and the living cells. This struggle is analogous to that which takes place between two different kinds of fungi, as before explained. It then becomes a question whether the vital forces of the human organism or those of the enemy are stronger; and whether the decomposition necessary to the growth of the fungi will take place. Under normal conditions the human organism will, as a rule, be victorious, because its powers of

resistance are well developed, and are specially adapted in this respect. But if local or temporary disturbances exist, and if the vital forces are on a low level, then the fungi may gain the day, and the result will be an infectious disease. *Naegeli* further explains that the infectious germs belong to the bacteria ; and he shows that, apart from the vital forces, two other circumstances are of principal importance in this respect. The soluble, non-nutrient substances must be mentioned first, as they always form a factor in the struggle, and do not vary, so far as the human organism is concerned. But the vital energy varies, and the number of bacteria which penetrate into the body may vary considerably ; it often happens that an organ which could resist the attack of a limited number of bacteria cannot prevail against a large number of them. *Naegeli* correctly remarks that this is a point of great importance, and until he understood it, he was doubtful whether there was any causal connection between the fungi and infectious diseases. He is of opinion that if a sufficient number of bacteria attack the body, the latter must succumb, even though it be in perfect health.

Secondly, the presence of foreign substances is equally important. In addition to the nutritive substances, all other soluble substances influence, and frequently decide, the result of the struggle. The same relations exist between bacteria and the cells of an organ, when a foreign or poisonous matter is present. This foreign matter will weaken one of the parties to the struggle, and will favour the other. Such substances, most of which are not normal constituents of the body, may either be products of the body itself, or they may penetrate into it, either alone or together with the bacteria. *Naegeli* is of opinion that these substances are chiefly products of decomposition, viz., substances which have either been formed independently of the human organism, by means of the various processes of putrescence, or within the body, as the products of certain diseases. However this may be, it is very probable that these substances are much less hostile to the bacteria than to the human organism, and *Naegeli* is of opinion that for this reason the struggle is often decided in favour of the bacteria.

To these observations made by *Naegeli* I add the following additional researches of my own. It is strange that *Naegeli*, who has investigated this subject so carefully, has not solved the

problem completely. For, instead of dealing simply and exclusively with the normal substances of the human body, and instead of directing his attention to the degree of concentration of the water in the tissues, he assumes, without reason, that there are certain unknown external substances, which he describes as giving the final decision in the struggle between the organism and the fungi. No doubt, such cases are possible, but it appears to me to be a much more important fact, that a high degree of concentration of the *normal* substance of the human body will suffice to determine the struggle in favour of the organism. It is remarkable how small the variations are which often decide the struggle between the fungi themselves. For example, differences of concentration of only 0·2 and 0·4 per cent. are sufficient to enable the bacteria in one case, and the yeast fungi in the other, to gain the victory. Comparing these percentages with the enormous differences of concentration which have been proved by my own, as well as by *Ranke's*, researches to exist in the parenchymatic juices of the human body, we can easily understand the great influence which these differences must exert in the struggle between the fungi and the tissue-cells.

Proceeding now with *Naegeli's* views, we come to another remarkable feature of the infectious diseases, viz., that persons who have contracted one or the other of them, enjoy for a greater or shorter period " immunity " from that particular disease. The explanation, that the disease destroys certain substances in the body, must be rejected from a physiological point of view, as wherever in organic nature a substance is removed from an organism, the latter sets to work to produce new quantities of this substance, in order to compensate for the loss. In infectious diseases the germs of infection usually find their way into the body in very small numbers. Consequently, if the liquids of the body are concentrated in a normal degree the fungi must perish. But if the condition of the organic liquids is for the time being abnormal, the bacteria are assisted to multiply, and to induce decomposition in the surrounding parts of the body. This process continues during the period of incubation, as well as during the illness itself. The vital forces of the fungi, allied with the products of decomposition which they induce, attack the organism, and, under these

circumstances, the development of the disease can only be suppressed by restoring to a normal degree of concentration, assisted by chemical reactions, the tissue substances which favoured the growth of the infectious fungi. Now, it is easy to understand that this procedure causes the patient to remain for some time "immune," *i.e.*, he will be protected from a fresh infection of the same kind of fungi ; and the more effective these chemical reactions in the organic liquids have been, the longer will this immunity endure. So far *Naegeli.*

This is another striking proof of how near he was to the final solution of the problem. But again he stops short, and gives no information as to what these normal and abnormal conditions of the organic liquids are, nor as to the nature of the chemical reactions of which he speaks. And yet it is evident, from his own investigations on the vital functions of the fungi, in what these factors consist, a subject which I shall fully discuss in the following chapter.

# XX.—THE DOCTRINE OF INFECTION.

(1878.)

I WILL now endeavour to combine my own researches with those of *Naegeli*, as they complement each other in a remarkable manner, supplying a complete theory of the nature of infection. I believe that this theory is as important for the practical suppression of infectious diseases as for their scientific explanation.

All that we have so far considered tends to prove that the amount of water in the tissues of the body is the principal factor in connection with infectious diseases. This leads us to the following law :—*Assuming all other functions and conditions of the body to be equal, immunity from infection increases as the amount of water in the tissues decreases.*

I. *Direct influence of the amount of water in the tissues.* The substances dissolved in any organic liquid must be separated into two groups, in respect of their behaviour towards bacteria, viz., (*a*) substances necessary for the nutrition of the bacteria, and therefore favourable to them, and (*b*) substances unsuited to this purpose, and consequently unfavourable to the development of the bacteria. According to *Naegeli*, both groups of substances are alike, in that their influence on the bacteria depends to a great extent on the degree of the concentration of the liquids in which they are dissolved. Matters in the living organism, injurious to the growth of the bacteria, can only be so when their concentration reaches a certain degree. Let us assume for a moment the impossible case that the fungi of infection use *all* materials of the living substance for nutritive purposes, thus leaving the body without any substances capable of resisting the fungi. Even in this state the body might expel the fungi, as we know from *Naegeli* that a certain degree of concentration is a *conditio sine quâ non* for the growth of the fungi. There is a high and a low limit to the degree of concentration

necessary for the growth of the fungi, and only when we have to deal with concentrations between these limits can the fungi multiply, and successfully attack the body. Hence the practicability of different methods of protecting the body against the attacks of bacteria.

1. By increasing the amount of nutritive substances until the higher limit of concentration is reached, in which the fungi cannot exist.

2. By enhancing the concentration of substances injurious to the fungi, or, if such antagonistic substances are absent, by adding them in sufficient quantities.

3. By withdrawing such quantities of water from the tissues of the living substance, that either the substances sub. 1. or those sub. 2. reach a degree of concentration at which the growth of the fungi is no longer possible.

II. *Indirect influence of the amount of water in the tissues.* The total amount of such water in the body affects the concentration of the contents of the stomach and the intestines. The lower the concentration, the more readily will infectious germs which attack the intestines—such as the germs of cholera, dysentery, and, probably, typhoid fever—multiply at an enormous rate, after the attack has begun, thus endangering the life of the organism. The rapid progress of the disease is hindered if the contents of the intestines are sufficiently concentrated; and this is in accordance with the well-known fact that the frequent use of liquid food-substances, as well as diarrhœtic dispositions, greatly increase the possibility and the danger of an attack of dysentery or cholera.

We have seen that infection supervenes after a struggle between the fungi which attack, and the protoplasm of the organism which resists. We have further learned that a decrease of the water in the nutritive solutions of the body diminishes the chances of the fungi, and increases those of the protoplasm of the attacked organism. We also know that an increase of the amount of water tends to obstruct the molecular *vitality* of the muscles, so much so, that if the amount of water is suddenly raised, apoplexy and even death may, in extreme cases, result. Similarly, the amount of water in the tissues influences every kind of animal protoplasm. In another respect a smaller amount of water in the tissues ensures immunity

from infectious diseases. As the germs of infection are not volatile, their entrance into the juices of the body, either by the mucous membranes of the lungs and of the intestines, or through the skin, depends on the *mechanical firmness* of the covering tissues, and this again is governed by the amount of water in the tissues ; for, if the surface cells of the mucous membranes are soft, and wanting in firmness, the germs of infection have little difficulty in finding their way through into the tissues. This is illustrated by the well-known fact, already mentioned, that a disposition to diarrhœa may greatly reduce the immunity from the cholera germ. Four different results of withdrawal of water from the tissues must be distinguished—

1. The germs are prevented from developing.

2. The entrance of the germs into the organism is rendered much more difficult.

3. The vital forces of the organism *in toto*, as well as of its organs, are increased.

4. The vitality of the fungi is weakened through the concentration of the nutritive solutions in the organism.

In short, the withdrawal of water lessens the chances of the fungi, and increases the vitality and immunity of the organism. In many cases a moderate diminution of the water in the tissues will suffice to decide the struggle in favour of the organism.

Apart from these theoretical considerations, the following practical reasons should also be borne in mind. It is generally admitted that infectious diseases, *e.g.*, typhoid fever, are more easily contracted, and become more dangerous, when the individual attacked is in an exhausted condition. The explanation is that a state of prolonged exhaustion induces an increase in the water in the tissues; this, coupled with the presence of the well-known fatigue-products, lowers the vital energy, and consequently improves the chances of the fungi.

Moreover, immunity from infectious diseases varies with the age of the organism, being greater during the more advanced periods of life, when the tissues gradually lose a proportion of their water. But not all infectious diseases are equally subject to this rule. For example, scarlet fever, measles, and diphtheria chiefly attack children, and smallpox is more

dangerous to young people than to older ones; while, on the other hand, the minimum of immunity from typhoid fever is not found during infancy, but at the age of 20 to 30 years. The explanation, according to *Naegeli*, is that not only too high, but also too low, a degree of concentration may prevent the fungi from multiplying.

Some kinds of fungi require a higher degree of concentration of nutritive substances than others, and all further increase or decrease of this concentration is injurious to them. This *optimum* of concentration for the development of the fungi is, as we have seen, by no means invariable. Moreover, it is notorious that in this respect great differences may exist among members of the same group of fungi. For example, in the group of the bacteria we see that the ordinary intermittent germ (as distinguished from the *pernicious* kinds) requires a much lower maximum of concentration than the germs of putrescence. This is proved by the fact that the germs of intermittent fever develop in stagnant water where fish can still live, while the germs of putrescence are unable to exist in a nutritive solution so little concentrated.

In connection with immunity caused by the withdrawal of water is another feature, which I may call *chemical immunity*. It comprises those cases in which an organism has previously been affected by an infectious disease. *Naegeli* correctly says that this chemical immunity must be due to the same cause which leads to the recovery of the patient, but he is incorrect in assuming that the common cause of both lies in the reaction of the organism. The explanation is, however, supplied by one of *Naegeli's* other investigations, which I have already cited, viz., that fungi producing yeast are destroyed by an accumulation of their own products of decomposition, if the latter are not volatile, but remain in solution.

My own view of this chemical immunity is that it is due to the fermentation products of the fungi. So soon as these cannot be promptly expelled by the patient, concentration necessarily sets in, preventing the further growth of the fungi, and thus ending the illness. So long as these substances remain in the body, more or less chemically united with the solid parts of the tissues, the organism enjoys a certain amount of immunity which, of course,

becomes less and less as the matter in the tissue-substances gradually changes. This chemical immunity is a characteristic feature of all infectious diseases, but we should bear in mind that it develops in different ways, and is principally of importance in infectious diseases of an *acute* character.

It is interesting to compare with these facts corresponding occurrences in the animal kingdom. Wild animals are known to be much more hardened against most infectious diseases than their domesticated relatives. The mode of living of the latter, without any struggle for existence, exercises the same influence as inactivity on the human body, *i.e.*, the specific gravity and immunity diminish; whereas wild animals are much more hardened, on account of the less easy conditions of their existence. A fact which well illustrates this decrease in immunity is a peculiar infectious disease among pheasants, which occurred near Stuttgart, in 1842, and coincided with a bad typhoid epidemic which raged in two neighbouring villages. This disease killed thousands of pheasants in the neigbouring royal parks, while their near relatives, the partridges, which lived in a wild state, were hardly affected. Infectious diseases among fish afford another example. They rarely occur in rivers, while they are frequent in fish ponds, where certain kinds, *e.g.*, carp, are kept, without the struggle for existence which is entailed in rivers by the presence of their dreaded enemy the pike.

## XXI.—CONSTITUTIONAL STRENGTH.
(1878.)

IN the preceding chapters we have exclusively dealt with infection, but many other diseases are also influenced by the withdrawal of water from the tissues.

Table IV. is of especial importance in this respect. The arrangement of this table is the same as that previously described in dealing with the tables I. to III. in chapter XVIII. It plainly shows that the diminution in the mortality of soldiers during the second and third years of service refers to almost all diseases. Hence, the influence of exercise in enhancing immunity, through the decrease of water in the tissues, is evident.

TABLE IV.*

*Mortality from different causes in the German Army from* 1867 *to* 1873, *excluding the period of the Franco-German War.*

| Names of Diseases. | Computed for the same number of men. | | | Difference between 1st and 3rd, as compared with 2nd year of service. Percentage. | | |
|---|---|---|---|---|---|---|
| | 1st Year of Service | 2nd Year of Service | 3rd Year of Service | 1st Year of Service. | 2nd Year of Service. | 3rd Year of Service. |
| Typhoid Fever ... | 1231 | 785·9 | 404 | + 43 9 | 100 | —48·6 |
| Cholera... ... ... | 166 | 89 | 61 | + 86·5 | 100 | —31·5 |
| Dysentery ... ... | 196 | 63·3 | 20 | +209·6 | 100 | —68·4 |
| Inflammation of the Lungs ... | 470 | 268·8 | 153 | + 74·9 | 100 | —43·1 |
| Catarrh and Inflammation of the Respiratory Tract... .. | 81 | 58·2 | 40 | + 39 | 100 | —51·4 |
| Pleuritis ... ... | 123 | 106·2 | 65 | + 15·9 | 100 | —38·8 |
| Peritonitis ... ... | 83 | 52·1 | 36 | + 59 | 100 | —38·6 |
| Nephritis ... ... | 58 | 40·88 | 27 | + 39 | 100 | —33·5 |
| Tuberculosis... ... | 428 | 414·8 | 361 | + 5·6 | 100 | —13 |

* For the explanation of this Table, see chapter XVIII., page 122.

The differences between the first, second, and third years are so striking that nobody will deny the importance of these statistical comparisons. Hypercritical persons who have followed me so far may perhaps object that all these comparisons prove nothing, and that the decrease of mortality in the army, according to the length of service, is due to the weeding out of the weaker constitutions, and to the survival of the fittest. This is, so far, correct, but it does not explain the primary question which underlies the whole problem, viz. :—*What is a strong, and what is a weak constitution?* This question has never hitherto been answered scientifically ; but, with the help of my statistics, I am now in a position to explain, and to define, what constitutional strength actually is. The specific gravity of the body is undoubtedly an exact measure of its constitutional strength. Therefore, a constitution is strong when it contains a maximum of albumen and salts, while a constitution is weak when fat and water prevail. This definition supplies the answer to the above hypercriticism. In military service we have to deal with two kinds of men, viz. :—

1. Soldiers whose protoplasm is so constituted that the albumen and the salts of the tissues are not strong enough to enable them to endure the hardships of military service, and who therefore die, or leave the army.

2. Soldiers in whom the proportion of albumen and salts has been raised through their military training, while the proportion of fat and water has decreased, and whose constitutions have thus been strengthened. We may therefore conclude that the constitution is strengthened by the withdrawal of water from the tissues, and by diminution of fat ; and that the extent to which it is strengthened may be measured by the greater or less specific gravity of the body.

I will add a few more remarks on the fats and salts of the body. We have found that, as a rule, water is the principal *materia peccans*. But long before it was recognised that the hardening of the body reduces the amount of water in the tissues, it was generally known that exercise and gymnastics cause a considerable reduction in the amount of fat, thereby, to a certain extent, hardening the body. The question whether the fatty substances are also a *materia peccans* must be answered in the

affirmative, because, undoubtedly, persons with a tendency to fatty degeneration contract illnesses more easily, and suffer from them more severely, than others who are without that tendency. Fatty substances, in large quantities, obstruct the circulation of the blood, as they mechanically impede the functions of the various organs. Moreover, *Ranke* has made the hygienically important discovery, that fatty degeneration is always accompanied by a corresponding diminution in the quantity of the blood ; and this must be injurious to health. For these reasons fatty substances should not be allowed to accummulate in the body. Both *water* and *fat* are *materiæ peccantes*, but it must not be forgotten that in each case an *optimum* exists which must be maintained, if the machine of the body is to be capable of doing the maximum amount of work. Secondly, as regards the *salts* of the body, and their relation to constitutional strength, it is important to know that they have a still higher specific gravity than the albuminous matters ; and numerous indications favour the assumption that an increase in the amount of the salts raises the constitutional strength of the individual. I will mention a few facts which bear in this direction.

1. It is well known that the bones of wild animals are more compact, and specifically heavier, than the corresponding bones of domesticated animals. This coincides with the fact that the constitutional strength of the former is greater than that of the latter. *Beneke* has found that the amount of salts in the bones of weak and unhealthy persons is much less than in those of strong and healthy individuals. My own investigations on the growth of bones* are in accordance with this statement ; and all these facts lead me to the conclusion that, apart from the gaseous and liquid excretions which leave the body when physical work is performed, there remains an insoluble substance in the body. This " insoluble ash," as we may properly define it, is deposited in those parts of the body which are only in passive motion, viz., the bones. We see that this " insoluble ash " is identical with bone-earth. Consequently, the relative quantities of bone-earth in two otherwise equal bodies indicate the amount of physical work which these bodies have performed. It is evident that this furnishes an

* See chapter XXVI.

equivalent of the amount of exercise which the soft parts of the body have performed ; and as constitutional strength is in direct connection therewith, it follows that *the specific gravity of the bones is an indication of the constitutional strength of an individual.* This explains another point of importance, viz., that the phosphates and the calcium compounds, which form the constituents of this "insoluble ash," play a more important part in physical work and exercise than has hitherto been assumed. Finally, the quantity of bone-earth contained in the body is not merely due to the *intensity* of the work, but also to the *time* in which it has been performed.

2. We know that an insufficient amount of calcium phosphates is an obstacle to the normal development of young animals, not only so far as the bones are concerned, but also in respect of the general constitution, as we have sufficient indications that calcium phosphate plays an important part in the formation of the tissues.

3. The fact that the principal substance of nerve protoplasm, viz., protagon, is a phosphorous compound, and that cell-nuclein is a compound of albumen and lecithin (the latter of which also contains phosphorus), proves that the action of the phosphates is closely related to the vital energy of the body. The amount of alkaline salts is of special importance, as they are capable of neutralizing the acid secretions of the body (carbonic acid, lactic acid, &c.). Sodium carbonate and dibasic sodium phosphate are of especial value in this respect.

4. We know that the proportion of salts in the tissue-juices influences the degree of imbibition of the protoplasm, and therefore the amount of water in the tissues.

5. Haemoglobin contains iron, an element of high specific gravity, and the amount of haemoglobin is in closest connection with the constitutional strength of the body.

Feeding-experiments with substances which have been deprived of their salts, prove how injurious to the animal organism is any diminution of the body's salts.

We are now in a position to clearly define the relation between constitutional strength and specific gravity.

First, the living substance is a mixture of substances of different

specific gravities. The heaviest constitutents are albumen and salts, and the lightest are water and fat. Albumen is the *materia laborans* among these different constituents.

Second, a decrease of the amount of salts below a certain limit is injurious to the vital functions.

Third, a certain amount of water is, of course, necessary for all vital functions; but any unnecessary surplus acts as a *materia peccans*, and, at the same time, as a *materia impediens*. Protoplasm is, so to speak, "living water," and the albuminous substances and salts are the agencies which impart to the water the characteristics of a living substance. The more of these substances the water contains, the greater will be its vital energy. Or, to use another comparison, protoplasm is an "aqueous solution of vital energy" (*sit venia verbo*); and the more concentrated the solution, the more energetic are the vital functions, while the less it is concentrated, the weaker is the vital energy. Here I must add some words about the so-called "latent life" of some lower animals. This state is produced by exsiccation. The extraordinary power of resistance against most possible agencies which these organisms show, when in this latent state of life, is a striking illustration of the influence of desiccation on the protoplasm. *Corpora non agunt nisi fluida* is an old saying which modern science has confirmed; and protoplasm without water cannot act (latent state). But as soon as imbibition sets in, the latent state ceases, and the vital energy increases in proportion to the *saturation* of the solution.

I believe that by the above explanations all doubt respecting the close relation between constitutional strength and specific gravity has been removed, and that the correctness of my discovery has been clearly established.

In conclusion, I will return once more to the hyper-criticism which I suggested might be made on my remarks on the mortality of soldiers. The practical value of these observations lies in the fact that military training has a sanitary influence upon the body. Theoretically, the principal gain is to have proved what constitutional strength actually is. This important function, which plays such a momentous part in biology, had not hitherto been accurately defined or measured; and as its nature and the

causes of its variability were not understood, no satisfactory results, either in theory or in practice, could be obtained. But I think that I have lifted the veil under which, until now, this mystery of organic nature was hidden ; and although the ultimate problem of the organic cosmos, viz., that of life, is not yet solved, we have at least obtained a clear insight into one of its most important functions.

## XXII.—THE TREATMENT OF INFECTIOUS DISEASES.

(1878.)

THE practical consequences of my doctrine respecting water in the tissues affect a great number of different diseases, but in the present chapter I shall limit myself to *infectious diseases*. As they are the most important group in connection with the subject-matter before us, we may hope to arrive at valuable practical results concerning their prophylactical, as well as their therapeutical, treatment.

Here I must refer again to *Naegeli*, who discusses the important question of damp houses and dwellings, and their sanitary influence on the occupants. *Naegeli* confesses that he has no idea why damp houses are so dangerous to health. He does not deny the fact, because it is too well known, but he says that a moist soil, damp walls, &c., prevent the infectious germs of the soil from penetrating into the dwellings, and that consequently a damp house is a *protection* against infection of this kind. *Naegeli* adduces various arguments to explain the noxious influence of damp houses, but it is clear that the fact that such houses are prejudicial to health does not seem to him to harmonise with the results of his investigations on the lower fungi. Here, again, my theory affords an easy and satisfactory explanation, viz., damp houses diminish the constitutional strength of their occupants, by interfering with the exhalation of moisture by the skin and the lungs, with the result that the amount of water in the tissues increases. I will not deny that, as *Naegeli* says, damp walls, &c., hinder infectious germs from entering dwellings; but as there are many other channels through which infectious germs may find their way into the body, the degree of immunity in this respect afforded by a damp house is not in proportion to the danger otherwise involved.

As regards the therapeutical side of the question, the conclusions to which I come are very simple. We have already seen that the germs of infection perish so soon as a degree of concentration of the excretions of the fungi in the juices of the body is reached, at which the fermentation and multiplication of the fungi come to a standstill.

The therapeutical methods have therefore merely to assist this concentration of the juices, by the withdrawal of water from the tissues of the body. It is interesting to note that the old medical schools, simply guided by empirical facts, recognised the importance of the withdrawal of water from the tissues. I have previously spoken of the *materia peccans* of the old schools; and the so-called "critical perspiration" is to this day held in high importance by the medical practitioner. I am convinced that the views formerly held in this respect are correct, although I do not rely on an unknown factor like the old *materia peccans*, for the simple reason that it is the water in the tissues which acts injuriously, so soon as it is present in excess. Of course, the crystalloid and gaseous substances, which, together with the vaporous and liquid perspiration, leave the body through the skin and lungs, are also of importance; and *Naegeli* is correct in saying that every excretion produced by an organism is a poisonous matter, if sufficiently concentrated. Water and carbonic acid form the greater part of the excretions of the living substance, and these are therefore the most dangerous excretions of the body. The injurious influence of carbonic acid is generally known, and is beyond dispute; but *water* has not hitherto been regarded as injurious, except in extreme cases. However, I have clearly shown its injurious nature, which explains the "critical perspiration" of the old medical schools.

The hygienic effect of the act of perspiration is twofold. First, perspiration is a proof that the victory in the struggle between the invading fungi and the organic tissues is on the side of the latter, because the withdrawal of water leads to increased energy on the part of the organism, and because the fungi will in consequence probably perish through their own excretions. Second, perspiration is equivalent to an acute dehydration, thereby enhancing the degree of concentration of the tissue-

juices. As soon as these influences, viz., concentration of the juices, and condensation of the fungi excretions, act together, the fungi perish, and the patient recovers. I find that all effective therapeutical methods of the present day are practically (if not intentionally) designed to effect dehydration of the body. For example, the requirement that sick-rooms be well ventilated is in direct connection therewith. The same may be said of the beneficial influence of cold air, because in cold air much more water is given off by the action of the lungs than in warm air. On the other hand, all conditions which prevent dehydration, *e.g.*, badly ventilated and overheated sickrooms, impervious bedding, uncleanliness, &c., &c., are notoriously unfavourable to the patient.

We now come to an important point, seemingly in contradiction to what I have hitherto explained, viz., the *drinking of water.* In reality no such contradiction exists, for we must always remember that we have not to deal with the fungi alone, but also with the protoplasm which they attack. The latter is subject to the same law as the fungi, viz., its own excretions are dangerous to the protoplasm. Now, experience teaches us that the protoplasm of a sick person produces more excretions than when the organism is in its normal state of health. These excretions must be expelled, and if dehydration of a patient suffering from an infectious disease were to be attempted, by refusing him anything to drink, not only the fungi would be destroyed, but also the tissue-cells of the patient. In short, the patient would perish, as well as the germs. It is therefore necessary to maintain a prompt exchange of liquids, taking care, however, that more liquid is given off than is consumed. If this treatment is successful, the noxious substances of the organism are carried off, and at the same time the concentration of the nutritive solution is increased to a degree at which the excretions of the fungi become injurious to them, with the result of the recovery and immunity of the patient. The therapeutical basis of this treatment is, that the excretions of the organism are more volatile, and easier to be removed, than the excretions of the fungi, thus enhancing the dehydration of the body, in spite of the necessary addition of water.

But it must be clearly understood that the success of this dehydration is dependent on raising the degree of concentration of

the body's tissues ; therefore, watery excretions which carry off considerable quantities of dissolved substances are injurious, and must be prevented. For example, it is often fatal when an infectious disease is accompanied by copious stools ; not only do the latter weaken the body, but the concentration of the tissue-juices suffers greatly if the patient then tries to make good the loss by consuming fresh quantities of water.

Here, again, the correct remedies have been used for a long time past, although the reason for their efficacy remained unknown ; they include the giving to patients who suffer from diarrhœa, &c., gruel, albuminous water, &c., &c., thereby preventing too great a dilution of the juices. But this constitutes only one half of the treatment. While seeking to suppress the excretions containing the substances which would assist concentration, we must endeavour to enhance the secretions consisting almost exclusively of water, and containing no solid substances. Evidently the two most important secretions of this kind are those of the skin and of the lungs, and these organs are much the most influential in promoting concentration of the body's juices.

Watery evaporation by means of the lungs is very effective in this respect, and possesses the additional advantage that it carries off the most dangerous of the organic excretions, viz., carbonic acid, together with other volatile acids. The respiration can convey no crystalloid substances, as it contains, with the exception of carbonic and other volatile acids, nothing but pure water. This explains the favourable influence of pure, cool air in the treatment of infectious diseases. We cannot, of course, go below a certain limit in this respect, but above this limit it is a rule that the colder the air, the more energetic becomes the process of respiration.

As regards evaporation through the skin, we must distinguish between volatile and liquid perspiration. These differ in their effect upon the concentration of the water in the tissues, as the former contains no crystalloid substances, while liquid perspiration contains sodium chloride as well as urea, both of which are important substances in connection with the proper concentration of the tissue-juices.

In view of the foregoing, it will be useful to shortly discuss an infectious disease of great importance, viz., *cholera*. We know

that cholera-stools carry off enormous quantities of water, but as they also contain a number of substances essential for the concentration of the tissue-juices, this removal of water has no concentrating influence, and does not prevent the rapid multiplication of the cholera germs. Therapeutically, our only means of obstructing the progress of these germs is to increase as much as possible the evaporation through the lungs and through the skin. But this cannot be done in the same way as in the treatment of typhoid fever, because in the latter case we have to expel the water and to lower the temperature, while in the treatment of cholera the water must be expelled, and at the same time the temperature maintained. I therefore recommend the application of hot dry air for the treatment of cholera in its first stages.

## XXIII.—PROPHYLACTICAL CONSEQUENCES OF THE DOCTRINE OF IMMUNITY.

(1878.)

THE simplicity of my doctrine of constitutional strength is of great practical advantage from the prophylactical point of view, and the following may be stated as a fundamental law :—the prophylactical treatment, when dealing with infectious diseases, as well as with all other pathological disturbances, should always endeavour to maintain the amount of water in the body's tissues at as low a level as is practicable. If we examine other doctrines on this subject, which have been found useful in practice, we shall see that all of them tend in the direction which I have indicated, although in this case, as in many others, practical experience has been a long way ahead of theoretical explanation. I have already explained that the quantitative value of the different functions by which water may be withdrawn from the tissues, differs considerably, the chief effect of concentration being obtained through the action of the lungs. This explains the well-known hygienic influence of all circumstances which favour this kind of dehydration. For example, energetic, active exercise, which produces a maximum amount of breathing, is of great value in this respect, as is also the inhalation of fresh, cool, dry air. An important limitation should, however, be made, viz., that the dehydration must neither be too sudden nor too intensive. As the last-named point is often misunderstood, I will explain it more fully. We have previously seen that a certain amount of water is necessary for the existence of every living substance, and, consequently, for the epithelal cells which cover the surface of the organs of respiration. If these cells are deprived of water by the too sudden action of very cold and very dry air, the risk is incurred of a local lesion, which may become dangerous, or even fatal. We must therefore bear in mind, that the organs which give off water should not be taxed in such a way as to cause local lesion ; and this not only holds good for the different organs in question, but also for the organism *in toto*.

With regard to the dehydration of the body *through the skin*, I must refer, in the first instance, to what I have previously said* on the difference in the effect between the gaseous and the liquid perspiration. Everything which favours uninterrupted and energetic invisible perspiration is of great hygienic value, and all circumstances which hinder the perspiration of the skin are direct and frequent causes of many diseases.

The injurious influence of moist air has long been recognized, especially in countries where rainy weather and swampy districts prevail; and damp dwellings and badly ventilated rooms come under the same category. All these points have often been discussed; but it is strange that another factor has never been investigated in its relation to the constitutional strength of the body, viz., the artificial covering of the human body.

It is not my intention to enter here into a discussion on the important subject of clothing, as I have done so in another publication to which I refer.† I will only mention one fundamental fact in this respect, viz., that *Pettenkofer* has experimentally proved that, as regards perviousness and slow conductivity of heat —the two most important hygienic factors in the question of clothing—no clothing-material can be compared with pure animal wool. From a zoological point of view, the fact that woollen clothing is the best wants no experimental proofs, as its truth is recognized by the simple observation that the wool and hair of the mammals, and the feathers of the birds, have been evolved by nature herself as the best means for covering the bodies of these warm-blooded animals. Not only are wool, hair, and feathers composed of the best substances for the regulation of the temperature of the body, but their structure, also, is specially adapted for this purpose. The extraordinary power of resistance of mammals and birds to all sorts of external influences is due to these two properties of their covering, whereby the normal temperature of the body is maintained.

If vegetable cellulose were a better covering-material for warm-blooded animals, it is certain that nature would have provided

* See chapter XXII., p. 147.

† HEALTH CULTURE, by *G. Jaeger, M.D.* Edited and Translated by *L. R. S. Tomalin.* Third Edition. London, 1895.

them with it, by producing hairs and feathers consisting of wood-cellulose. So long, therefore, as we are in a position to cover the body with animal fibres, vegetable fibres should, under no circum stances, form an essential portion of our clothing and bedding.

Coming now to the mechanical part of the question, we have, in the first place, to consider that those parts of the body where the principal arteries have their terminal capillaries must be well protected, because all regions of the blood-circulation which lie between the heart and the terminal capillaries become dilated under the influence of higher temperatures. These regions include the extremities of the arms and legs, as well as the anterior medium line of the trunk. Therefore, in order to dilate, *e.g.*, the whole artery system of the arm, we must keep the hand and the wrist warm. The treatment of the leg is quite analogous. The injurious influence of cold hands and cold feet is notorious, and the comfortable feeling when hands and feet are warm is equally well known.

In conclusion, I will add a few remarks on the therapeutical treatment of non-infectious diseases. In dealing with acute illnesses, the old therapeutical schools regarded perspiration, purgation, and diuretic treatment as of principal importance. In fact, their chief object was to increase all watery secretions of the body. But many adherents of our modern physiological school are opposed to this treatment, as they do not consider water, under ordinary circumstances, to be a *materia peccans*; and they only regard it as such, and endeavour to get rid of it mechanically, when it penetrates as an œdemous fluid into the interstices of the tissues, or as a hydropic liquid into the serous cavities. I think I have succeeded in proving that the views of the old schools, so far as the diaphoretic treatment is concerned, are physiologically perfectly justified. Of course, we have no specific "disease matter" to deal with, as they assumed; but the presence of an excess of water in the tissues is sufficient by itself to explain the origin and nature of many diseases. The effect of copious perspiration at the beginning of an acute illness is—

1. We improve the constitutional strength of the tissues, and increase their immunity against all attacks by which they are threatened in the course of the disease.

2. We improve the mechanism of the nervous system by diminishing the sensibility of the nerves, and by increasing, at the same time, the conductivity of the regulating mechanism of the nervous system.

3. By diminishing the tension of the tissues, and the pressure of the blood, the mechanism of the circulation is improved.

When a physician is called to a patient who suffers from an acute or feverish attack, his first business should be to find out whether a lesion or other mechanical injury has taken place, or whether a poisonous or other foreign substance has found its way into the body. If this is not the case, he can safely conclude that he has to do with an obstacle to conductivity in the body's mechanism. Physiological experiments have proved that obstacles of this kind are mostly due to water. If the physician bears this in mind, and takes proper steps to get rid of the surplus water, the patient will in most cases recover, without further complications. Withdrawal of water from the tissues must therefore be the starting-point in the treatment of all such complaints. This is the best way of dealing with acute illnesses ; but in chronic diseases it is of great importance to ascertain at the outset the exact specific weight of the body, as by this means an insight will be gained into the general state of health of the patient. All so-called constitutional, or natural, cures have one thing in common, viz., that they enhance the dehydration of the body ; and I am therefore of opinion that chronic dyscrasies, and probably many local chronic affections, can also be dealt with by the treatment indicated.

The absolute weight, which has hitherto been the only basis for noting the effect of a cure, is by no means sufficient ; in serious cases the specific weight is a much more reliable guide to the general state of the patient, as well as to the effect of the medical treatment. To have proved this, and to have explained the connection between constitutional strength and specific gravity, is the principal discovery which I have made in connection with this important subject.

## XXIV.—VARIATIONS IN THE MODE OF LIVING.*

(1878.)

IF we investigate the actual nature of work, we find that work is a motion, and every motion is the consequence of a disturbance of an equilibrium. A machine can only be kept in motion by the continuous disturbance of its state of equilibrium, and exactly the same holds good for the activity of organisms. We have previously seen that the activity of some of the most important parts of the organism, viz., nerves and muscles, is due to disturbances of the equilibrium of their molecules. Further, we have seen what an important part the different processes of diffusion play in connection with the vital activity of the body. Finally, we know that the source and origin of all energy developed by the organism are due to elasticity, in connection with chemical affinity. So long as the blood, by means of the circulating system, is kept in proper motion, an equilibrium of diffusion is evidently impossible. It should be added that the blood is constantly in motion between the capillary vessels of the lungs and the other parts of the body, inducing changes in the amount of carbonic acid and of oxygen which are antagonistic to the body's welfare. A similar relation, as regards the composition of the blood, exists between various other organs of the body. The most remarkable fact in connection with these changes is, that the peculiar self-regulating action of the heart causes every diminution of the difference in composition between the blood and the tissue-liquids to increase the heart's activity, and *vice versâ*. In spite of all regulating arrangements, however, tending to prevent a state of equilibrium, we find that these precautions are by no means complete. This is due to the physiological factors commonly described as custom and

* Some practical applications in connection with this chapter will be found in *Dr. Jaeger's* HEALTH CULTURE, edition of 1895, pp. 170-183, to which I refer. —The ED.

habit, which are a consequence of the daily mode of living of the majority of civilised human beings. It is therefore necessary to counterbalance this inadequacy of the regulating apparatus by certain periodic changes in the daily mode of living, in order to prevent the otherwise inevitable tendency to a state of equilibrium injurious to health. As this matter is one of great practical importance, I will subdivide my observations under different headings.

1. *Change of Occupation.*—Division of labour is an essential factor in intellectual, as well as in corporeal, work. Close adherence to a special form of occupation diminishes the quantitative and qualitative working-capacity of the individual. For example, it is a mistake to suppose that periodic change between waking and sleeping, between work and rest, and even change in the work itself, suffices to maintain health and working-capacity. A man who constantly works requires, to maintain his working-capacity at its proper level, not only a day of rest after six days of toil, but also, at irregular times, a holiday during which he can completely change the nature of his activity.

A further very important point is the change in the intensity of energy employed. In many cases a certain excess of energy has a favourable influence upon both body and mind. Exceptional activity, coming under the definition of pleasure, deserves especial consideration in this respect. Joyful emotion has been proved to exercise an important influence on the exchange of the albuminous substances of the body, while grief and sorrow produce an opposite effect, *i.e.*, they retard the exchange of matter. We know, for instance, that joyful emotion increases the activity of the heart ; and I conclude from these facts that joy must have a favourable influence on the health and vital energy, and that every increase in the exchange of matter is, physiologically considered, a hygienic factor. This has long been recognised in our daily life, and the ancient Romans knew well that a man who works requires not only *panem*, but also *circenses*. On the other hand, physicians are well acquainted with the fact that prolonged depression is capable of inducing serious bodily disorders. This is the physiological explanation of the injurious nature of the sweating system, not only to each particular branch of industry in which it is practised, but also to the

community in general. It is a very bad policy to pay officials and workpeople so little that they are not in a position to enjoy any or the usual pleasures of life ; for the pecuniary saving effected by paying small wages is counterbalanced, and rendered illusory, by the fact that such underpaid employees are, in the long run, incapable of doing their work properly. My views on the physiological influence of pleasure lead me to mention a question of great practical importance, viz., the physiological value of athletic sports. It is often said on the continent that compulsory military service renders sports unnecessary. Training, exercising, the yearly manœuvres, and so on, are thought sufficient to maintain at a high level the working-capacity and the constitutional strength of the male population. But if we compare the Continental States with Great Britain, where various athletic sports are one of the chief causes of the high development of the population, we see at once what an enormous physiological importance attaches to this kind of pleasure. Moreover, the assertion, which is often heard on the Continent, that sports are all right for people who have nothing to do, but should not be indulged in by men who have to work for their living, is altogether erroneous. I contend that sports are of the utmost importance for the production and maintenance of energy, pluck, and working-capacity ; and the more so because they are not confined to a limited number of years, like the military service on the Continent, but may be practised during the greater part of the human life. To this we must add the physiological influence of pleasurable excitement, which, together with the invigorating effect of bodily exercise, fresh air, and so on, enhances the exchange of matter, and thus has a healthy and hardening effect upon the body. It is no exaggeration when I say that the high qualities to which the British owe their position as the principal colonising, commercial, and industrial nation of the globe are largely due to the high development of sports in the United Kingdom, as well as in the British colonies. There is a great difference between the training derived from sport and that which is supplied by military drill. The advantage, both to body and mind, is decidedly with the former, and we see that the British nation, while enjoying greater freedom of action, and a higher degree of personal liberty, than is permitted

by any of the Continental States, is nevertheless as well organised, and as law-abiding, as any of the latter.

2. *Change of Food.*—During the Franco-German war, observations on a considerable scale proved that even the best and most nourishing kind of food is injurious to health, when it has formed for a certain time the sole form of nourishment. Our daily life confirms this, as we find that every kind of food, if we restrict ourselves to it, produces, after a short time, a feeling which is not so much satiation as distaste ; and that is the reason why it is usual to aim at a change of fare. This feeling is by no means imaginary or whimsical, and has a close connection with the function of digestion. In this case, also, we possess what amounts to a regulating apparatus, whose action we must watch, if we wish to be in good health. The first and most prominent effect of monotonous food on the stomach and intestines, is slower digestion, accompanied by waste of food, as a smaller quantity is assimilated. This is especially the case with people who lead a sedentary life, and who must therefore be careful to observe a proper change of food. But the injurious effects are also distinctly noticeable in the vital energy. Monotonous food makes a man lazy and apathetic, and his working-capacity declines. The vegetable kingdom shows an analogous effect, as it is well known that when a soil is continuously cropped with the same species of plants, degeneration sets in before the materials on which the plant feeds are exhausted. It is not, therefore, the want of food-substances which produces this degeneration, but probably a certain equilibrium of diffusion between the tissue-juices of the plant and the salt solutions of the soil. The injurious influence of monotonous food on the animal organism is due to a similar cause. The contrast between the digestive juices and the blood, on the one hand, and the food in question on the other, becomes less and less, and the consequence is a corresponding decrease of the diffusion-processes in the intestines, as well as in the blood and tissue-juices. Therefore, a change of food becomes absolutely necessary, not only for the bodily, but also for the mental, welfare of the individual. I have carefully studied the following practical rules, which may be found useful in this connection : (*a*) The principal daily meal should always consist of a variety of different dishes, which ought to be in

harmony with one another. (*b*) We should not eat the same kind of food twice in one day. (*c*) The principal foods should be appropriately changed, not only from day to day, but also in the course of the different seasons of the year.

These rules should be strictly adhered to, but I should not like to give the impression that I regard a luxurious mode of living as essential to health. On the contrary, a man who dines every day on a great variety of dishes has much less chance of proper physiological variety in this respect than one who lives on plain fare, as the chemical and physical difference between two dinners of many courses must of necessity be much smaller than the difference which a limited number of dishes affords. In this case, as in many others, I recommend the *aurea mediocritas* as the best practical solution of the problem.

3. *Change of Air.*—The importance of this change is so generally known that I need hardly point out its significance from a hygienic point of view. After we have been for some time in the warm atmosphere of a room, we breathe with delight the pure, cool outdoor air, which acts invigoratingly on the body. And, *vice versâ*, when we return from a long walk in fresh and cool air, we find the warm and quiet atmosphere of a room agreeable and invigorating to mind and body, provided that it is not stuffy, or otherwise impure.

The same difference exists between the dry, pure air of open tracts of land and the moist air of forests, or between the thin air of mountain peaks and the denser atmosphere of valleys. Every such change of air produces a healthy disturbance of equilibrium, which has a stimulating influence upon the totality of the corporeal actions. Of course, we must not forget that an excess of these stimulating influences may become injurious, as we know that sudden differences in the temperature, pressure, and moisture of the air may cause serious disturbances in the circulating system. But, within proper limits, a change of air is always of advantage to health, and to neglect this factor for a considerable time is equivalent to a decrease in vital activity. The first change which we have to consider, concerns the medium which usually surrounds us. I refer to *bathing*, which is a change from the surrounding medium of air to that of water. It is not practicable to enter, on this

occasion, into details about bathing, but I will mention some general rules in this respect. The chief hygienic consideration is, that regular baths *of the same kind* should be avoided, for reasons analogous to those given above in respect of food. It is a mistake to accustom the body to regular baths, especially when they are tepid or hot. The result is that they cease to have the proper stimulating effect upon the organism. The same is the case with cold baths, but in a less pronounced degree. If a healthy man periodically changes between cold baths, warm baths, vapour or Turkish baths, he will find this to have an invigorating effect upon the body. Moreover, the daily change between the open air and the atmosphere of rooms is too well known to be discussed in detail. I will only add that the daily constitutional walk should be supplemented from time to time by excursions extending over a somewhat longer period of time, and to places where the air differs from that which we usually breathe. For instance, we may exchange the air of valleys for that of mountains, of forests for that of rivers, of town for that of the country. The next step in respect of change of air is the annual holiday, which is just as essential to health as all that we have so far discussed. During the annual holiday, we should endeavour to alter as much as possible our whole mode of living, in order to completely shake off the monotony, and tendency to ailments, which usually accompany our daily life. The best change in this respect is the difference between an inland and a maritime climate. Those who live in the interior of a continent like Europe, should spend their holidays on the sea-coast, while those who live in the vicinity of the ocean cannot do better than travel to the interior of a continent, and especially to mountainous districts, as far away from the sea as possible. If all these points are considered, without going to extremes, we shall find that a proper change of air is a great sanitary factor in our lives.

4. *Change of Blood.*—Here we have to deal with a most interesting subject, which exercises an enormous influence upon constitutional strength, because it is one of the most important factors connected with the propagation of the species. As regards domesticated animals, it has long been known that the degree of similarity which exists between the parents has a great

influence on the constitution of their offspring. If there is a high degree of constitutional equality between the parents, we find, in the first instance, that fertility is much reduced, and, secondly, that the constitutional strength of the issue is considerably lower than when the parents differ to a certain extent from one another. This decrease in constitutional strength becomes evident by the fact that such animals have much less power of resistance to many diseases, and that monstrosities and other defects are more frequent among them. An important factor in the development of man and animal is what I may describe as a *difference in the blood* between the parents. The actual nature of this difference in blood, and its causes, are only imperfectly known. The most familiar fact in connection therewith is, that the difference is smallest where the relationship between the parents is closest, and *vice versâ*. When, however, the difference becomes too great, we arrive at a point where two varieties are *crossed* with one another. *Darwin*, *Nathusius*, and others have made many interesting experiments with animals, showing the important influence of greater or less difference in blood. In a previous chapter * I have explained the influence of close-breeding in connection with animals, and I will now add a few remarks with reference to human beings. In villages or mountainous districts, where, for many generations past, intermarriage between a limited number has been frequent, and where both sexes lead almost exactly the same life, we find, as a rule, a degenerate population, bodily and intellectually inferior. In this case, as in others which I have already mentioned, we see how injuriously neglect of the laws of change affects development. On the other hand, in places and countries where a change of the population, and an influx of foreign blood, can easily take place, as is the case in large towns, we find a race intellectually and bodily developed, owing to the constant change and difference in blood. Examining the problem further, we notice that the injurious influence of close-breeding in small communities considerably decreases so soon as one portion of the inhabitants (usually the male population) has been absent for a certain time, and subject to a different mode of living. Thus, inhabitants of the mountainous

* See chapter V.

districts of the Tyrol, Savoy, &c., &c., who are in the habit of migrating, when young, for a period of years, are a well-developed and strong race. Generally speaking, a different mode of living for the male and female sex appears to me to be often of greater importance than actual relationship, because when the parents are subject to a similarity of the general conditions of existence, we notice that the offspring is liable to deteriorate. From this point of view, the continental system of compulsory service in the army is of great physiological value. The difference established in the adult male population, after prolonged absence in military service, has an important influence on the subsequent propagation and development of the race.

Our information respecting savage nations and tribes fully confirms these facts, and *Darwin* and *Livingstone* have both adduced striking examples from the African and American aborigines in this respect.

## XXV.—PHYSIOLOGICAL INFLUENCE OF VARIETY IN WORK.

(1878.)

OWING to the great differentiation and division of labour, the physiological influence of a customary daily occupation upon the working-capacity and health is difficult to define. Almost every occupation is subject to particular conditions in the mode of life of the worker; and in many occupations the substances and materials with which the worker has to deal affect certain of the chemical and mechanical functions of the organism. It is not, however, my intention to deal with this side of the question, as I propose to discuss, in the present chapter, the physiological effect of the customary daily task on the working-capacity. The most general observation in this respect is that work, as compared with passivity, disposes the body to be more energetic and active. All work enhances specific skill in a particular occupation, especially in connection with the effects of training and exercise.* At the same time, the working-energy, as compared with inactivity, acts as a sanitary factor, by increasing the exchange of matter and the transmutation of forces, without which the living substance cannot exist.† Work alone, however, cannot keep the body at the highest pitch of activity and energy, and in this connection we have to consider various important factors. There is, first, the contrast between what we may term the mechanisms of energy (nerves, muscles and bones), and the auxiliary mechanisms (respiration, circulation, nutrition, and excretion). From the point of view of economy in working, as few organs of the body as possible should be used, especially where the auxiliary mechanisms are concerned; otherwise, energy may often be wasted, especially as regards the heart and lungs. On the other hand, we know that every mechanism of the body can only reach its highest working-capacity when it has been

* See chapter XVII. † Compare chapter XV.

sufficiently exercised, *e.g.*, untrained lungs cannot do as much work as lungs which are trained, and are more liable to be out of order. The same rule holds good with the organs of the circulating system, and, in general, with all auxiliary organisms of the body. Consequently, most daily occupations expose the inner auxiliary organisms of the body to the danger of deterioration by non-use, or insufficient use ; and it is necessary to counterbalance this tendency by some kind of recreative work, as different as practicable from the usual daily occupation. The object of the recreative work is to restore and increase the activity of the inner auxiliary mechanisms ; and the change becomes absolutely necessary in those occupations which afford little or no opportunity to bring the auxiliary mechanisms regularly and adequately into play. The chief contrast in this respect is between *sedentary* and *active* occupations. In the former we usually employ the arms and hands, the muscles of which (from a quantitative point of view) are far inferior to the muscles of the lower extremities. Active occupations, on the other hand, with regular and energetic locomotion, &c., bring the muscles of the lower extremities extensively into play. The physiological difference between a sedentary and an active life is therefore especially remarkable in respect of the heart and lungs. We know that the exercise achieved during an ordinary walk causes the pulse to become stronger and quicker than when we quietly sit at the desk, and the same may be said of the respiratory functions.

If, in consequence of a sedentary life, the lungs are not properly used, the following functional changes take place :—

(1) The mobility of the thorax decreases.

(2) The walls of the chest and lungs are liable to grow together.

(3) If, when the lungs are insufficiently exercised, plentiful nourishment is taken, fatty degeneration usually sets in, which injures the functions of respiration, by obstructing the motions of the diaphragm.

(4) When the lungs are not properly exercised, their tissues lose in elasticity and faculty of tension, and thus the transit of air and blood is impeded.

(5) The normal sustenance of the tissues of the lungs suffers, as will be seen from the following facts :—Phthisis is not only a most

dangerous lung disorder, but is also, generally speaking, one of the most fatal of diseases, as, according to *Niemeyer*, not less than one-seventh to one-fifth of all deaths among civilized nations are due to phthisis; and the average for the populations of large towns is still greater. In contrast with these exceedingly high figures in civilized life, we find that among the savage races, the gipsies, and so on, phthisis is almost unknown, as a roving and outdoor mode of life necessitates considerable exercise of the lungs. That a disposition to this terrible disease is principally due to inadequate exercise of the lungs, is proved by the following facts:—

(1) Phthisis nearly always first attacks the tips of the lungs, which, in sedentary occupations, are inadequately used; as in ordinary respiration, by means of the diaphragm, only the lower parts of the lungs come into play.

(2) Women make more use than men of the tips of the lungs, in so-called chest-respiration, and this difference is strikingly illustrated by the statistics of phthisis. It is true that, generally speaking, both sexes are equally attacked by phthisis; but I believe the reason to be that external influences, such as foul air, affect the female sex more than the male. The investigations of *Emil Müller* have clearly proved that, where the external conditions are equal, the mortality from phthisis is much less with females than with males.

(3) An incongruity exists between phthisis and emphysematic complaints, *i.e.*, emphysematic lungs rarely become consumptive.

(4) The mortality from phthisis is much larger in occupations which cause the lungs to be relatively little used, than in those which require them to be regularly exercised.

Another effect of exercising the lungs is shown in cases of acute inflammation of those organs. Lungs which have been inadequately exercised are less capable of holding and transmitting air and blood; and if inflammation sets in, the lungs will cease to perform certain portions of their functions. The parts of the lungs which remain intact must then do the whole work of respiration, *i.e.*, most of the blood which comes from the right lobe of the heart will pass through them. Inflammation of the lungs is much more dangerous under these circumstances, than when the parts affected remain capable of performing their functions, owing to their having been regularly exercised.

## XXVI.—THE LONGITUDINAL GROWTH OF THE HUMAN BONES.

IF we hold that the different forms of the organic world have developed from other and previous species, we must investigate the influence to which the variability of the human body is due. *Lamarck* was the first to point out a morphological influence which can be experimentally proved to cause variations, even in grown-up organisms. This influence is *the enhanced use of an organ or a group of organs*, a fact on which *Lamarck* based his well-known doctrine of the development of the animal kingdom.

But *Lamarck's* doctrine was not accepted by the scientists of his age; and this morphological influence has only been investigated to a very slight extent by breeders of domesticated animals, such as *Nathusius*, while, in more recent times, the advocates of gymnastic exercise have also paid attention to the subject. In both cases practical advantage has been taken of the fact that increased use of a part of the body changes its anatomical qualities. My investigations on the effects of the upright posture on the structure of the human body obliged me to further inquire into this morphological influence; and I thus came to the conclusion that many proportions of the human body, which had not hitherto been regarded as variable, are evidently due to this influence. I am confirmed by the researches of Professor *Meyer*, in Zürich, who (starting from quite a different point of view) arrived at the same conclusion, viz., *that tensions and pressures exercise a considerable influence on the development of the human skeleton.* My investigations commenced with the bones of the human tarsus, which is well-known to be distinguished from that of the quadrupedal animals by a number of essential features:—

1. The human tarsus is obliquely placed, in such a way that only the outer edge touches the ground. Among the animals, only the anthropoid apes appear to have a similar arrangement of the tarsus. As man is born with an oblique position of the tarsus, we see that this anatomical feature of the human skeleton is inherited.

2. The two other specific features of the human foot are the turning-down of the different bones of the arch of the foot, and the more pronounced development of the first and the fifth metatarsi. As neither of these features is met with elsewhere in the animal kingdom, not even among the anthropoid apes, it appears nearly certain that these features are *adopted*, and are not, like that previously mentioned, inherited.

When I first ascertained this fact, I was of opinion that the term "adopted" meant, in this case, a process coinciding with the development of the human species; but so soon as I more closely examined the feet of new-born infants, I found that the word "adopted" has, in this connection, a much deeper significance. A new-born infant does not show this turning-down of the bones of the arch of the foot; on the contrary, they lie parallel with one another. The sole of the foot of a new-born child is therefore without the characteristic curvature; it is flat, and does not lie horizontally, but forms an angle of almost 45 degrees with a horizontal plane *(see figure.)*

A similar process takes place when the outer and the inner metatarsus bones become stronger. It is true that the metatarsus bone belonging to the great toe is, from the first, somewhat larger than the bones in the middle; but, in respect of the outer bone, we find no trace of the considerable enlargement of the end of the tarsus, and of the less enlargement of the *capitulum*. After ascertaining this, I came to the conclusion that these two important anatomical features of the human foot are not inherited, but are acquired later on in life. Investigating more closely, I found that when an infant first tries to walk, the turning-down of the metatarsi is at

first casual and temporary. When the infant sits, or lies on its back, the turning-down is not at all noticeable, and only takes place by voluntary movement of the muscles in question during the short intervals when the child tries to stand. The more frequently this act is performed, the less complete is the reversion of the bones to their original parallel position. We here see an important anatomical change in the skeleton of the human foot, directly influenced by exercise and use. This is a much more satisfactory explanation than the view hitherto taken, viz., that the curvature of the sole is fore-ordained, and that the upright posture of man is the consequence of this favourable arrangement of the human foot. I think that I have proved the converse, viz., the child tries to raise itself, assisted by its hands and arms, and supported by its legs, with the result that the metatarsi, especially their anterior ends, are pressed against the ground. This act is as much a voluntary motion of the muscles as the grasping motions of the meta-carpal bones, when the hand of the child tries to hold an object. After a while, the metatarsi retain more and more this new position, following the same laws as govern the fixing of any other joint of the body which has remained in a given position for a lengthened period. It is evident from what I have said, that the *conditio sine quâ non* of the upright posture of man is the capability of his hands to grasp ; and he can therefore only have developed from mammals provided with this kind of hand. Inasmuch as the features in question are not merely individually adapted, but are due to use and exercise, I came to the conclusion that, in all probability, the peculiar enlargement of the outer metatarsi is also due to the same cause.

Such knowledge as we possess respecting the growth of this bone favours the assumption that the lateral growth depends on the periosteum, while the longitudinal growth is due to the cartilagenous discs inserted between the epiphysis and the diaphysis. I am inclined to think that every irritation of these two bone-producing tissues may, under favourable circumstances, increase the production of bone-substance in both a lateral and a longitudinal direction.

I am therefore of opinion that the larger development of the outer and inner metatarsus bones is chiefly due to use and exercise,

especially as the upright posture causes these two bones to do the principal work. In order to conclusively prove this, I made a series of measurements of individuals of various ages, with the following results :—

| No. | Age. | Sex, or Occupation. | 1st Metatarsus. | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|---|---|
| | | **1. Family.** | | | | | |
| | | | Mm. | Mm. | Mm. | Mm. | Mm. |
| 1 | 8 Months | Boy | 16 | 11 | $8\frac{1}{2}$ | $8\frac{1}{2}$ | 10 |
| 2 | $2\frac{1}{2}$ Years | Girl | 16 | 9 | 8 | 8 | 10 |
| 3 | $3\frac{1}{2}$ ,, | ,, | 18 | 11 | 9 | 9 | 12 |
| 4 | 5 ,, | ,, | $19\frac{1}{2}$ | $12\frac{1}{2}$ | 9 | 9 | 12 |
| 5 | 6 ,, | Boy | 20 | 13 | 10 | 11 | 13 |
| 6 | 35 ,, | Man, sedentary life. | 38 | 14 | 15 | 18 | 25 |
| 7 | 32 ,, | Woman | 29 | 15 | 15 | 12 | 19 |
| 8 | 26 ,, | ,, (Servant) | 30 | 14 | 15 | 15 | 24 |
| | | **2. Family.** | | | | | |
| 9 | 9 Years | Boy | 22 | 11 | $9\frac{1}{2}$ | $10\frac{1}{2}$ | 16 |
| 10 | $18\frac{1}{2}$ ,, | Mechanic | 36 | 14 | 12 | 12 | 26 |
| | | **3. Family.** | | | | | |
| 11 | $5\frac{1}{2}$ Years | Girl | 24 | 13 | 12 | 11 | 15 |
| 12 | 9 ,, | ,, | 26 | 12 | 10 | 14 | 16 |
| 13 | 10 ,, | ,, | 32 | 14 | 12 | 14 | 18 |
| 14 | 12 ,, | ,, | 30 | 13 | 11 | 12 | 17 |
| 15 | 14 ,, | Boy | 39 | 19 | 11 | 15 | 25 |
| 16 | 39 ,, | ,, | 3· | 14 | 15 | 18 | 25 |
| 17 | 39 ,, | Woman | 40 | 19 | 13 | 15 | 26 |

4. FAMILY.

| No. | Age | Sex. or Occupation. | 1st Meta-tarsus. | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|---|---|
| | | | Mm. | Mm. | Mm. | Mm. | Mm. |
| 18 | 13 Months | Boy | 15 | 11 | 10 | 11 | 12 |
| 19 | 5 Years | " | 20 | 11 | 9 | 10½ | 14½ |
| 20 | 33 " | " | 41 | 14 | 13 | 14 | 26 |

5. FAMILY.

| No. | Age | Sex. or Occupation. | 1st Meta-tarsus. | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|---|---|
| 24 | 2 Years | Girl | 18 | 11 | 11 | 10 | 14 |
| 22 | 4¾ " | " | 20 | 12 | 10 | 10 | 16 |
| 23 | 39 " | Man | 36 | 15 | 13 | 17 | 24 |

These tables show that the great and the little toe, or, rather, the ends of their metatarsus bones, increase in thickness with advancing age, as compared with the other metatarsus bones.

After I had arrived at these results, I was led to investigate whether the measurements of other parts of the human skeleton also bear witness to the more energetic growth produced by increased use and exercise. As it is impossible to measure the absolute thickness of the bones of the living body, I had to limit myself to their longitudinal growth. I therefore tried to ascertain whether the bones which the upright posture of the human body causes to be subject to the pressure of a greater weight, are relatively longer in adults than in new-born infants. This was completely confirmed, as the subsequent tables will show.

My first measurements in this connection dealt with the longitudinal proportion between trunk and leg. According to *Liharzic*, the average length of new-born infants is 50 ctm., of which 30 ctm. is the length of the trunk, and 20 ctm. that of the leg. According to the same authority, the normal height of an adult man is 175 ctm., of which 81 ctm. represents the trunk, and

94 ctm. the leg. Thus the proportion is completely changed as compared with that of new-born infants. My own experiments confirm this, as the following table shows :—

| Age. | Sex. | Trunk. | Leg. | Percentage of Total Length. |
|---|---|---|---|---|
| 8 Months ... ... | Boy | 38 Ctm. | 30 Ctm. | Leg 44 |
| $2\frac{1}{2}$ Years .. ... ... | Girl | 46 ,, | 37 ,, | ,, 44·6 |
| $3\frac{1}{2}$ ,, ... ... ... | ,, | 51 ,, | 42 ,, | ,, 45 |
| 5 ,, ... ... ... | ,, | 55 ,, | 48 ,, | ,, 46·6 |
| 6 ,, ... ... ... | Boy | 55 ,, | 50 ,, | ,, 48 |
| 35 ,, ... ... ... | Man | 84 ,, | 86 ,, | ,, 51 |
| 32 ,, ... ... ... | Woman | 77 ,, | 83 ,, | ,, 52 |

This proves that, with advancing age, the leg grows more quickly than the trunk, *i.e.*, the part of the body which supports has a greater longitudinal growth than the part supported.

I then investigated the proportions between arm and leg. The following table gives the results obtained :—

| Age. | Sex. | Arm. | Leg. | Difference. |
|---|---|---|---|---|
| 8 Months ... ... | Boy | 29 Ctm. | 30 Ctm. | 1 Ctm. |
| $2\frac{1}{2}$ Years ... ... ... | Girl | $33\frac{1}{2}$ ,, | 37 ,, | $3\frac{1}{2}$ ,, |
| $3\frac{1}{2}$ ,, ... ... ... | ,, | 37 ,, | 42 ,, | 5 ,, |
| 5 ,, ... ... ... | ,, | $42\frac{1}{2}$ ,, | 48 ,, | $5\frac{1}{2}$ ,, |
| 6 ,, ... ... ... | Boy | 41 ,, | 50 ,, | 9 ,, |
| 35 ,, ... ... ... | Man | 68 ,, | 86 ,, | 18 ,, |
| 32 ,, ... ... ... | Woman | 66 ,, | 83 ,, | 17 ,, |

The table plainly shows that these parts of the body follow the law which governs those already mentioned.

The next subject of my measurements was the spinal column, and it is at once evident that here the same law holds good, as we notice that in all parts of the spinal column increased pressure enhances the longitudinal growth of the bones. In the subsequent table I give the longitudinal measurement of the vertebrae of an adult man and a new-born infant. I intentionally omitted from this table the two first cervical vertebrae, because the atlas and the epistropheus combine together, and their functions do not allow a direct comparison with the other vertebrae. For a similar reason I did not measure the *os sacrum*.

| Vertebrae. | Adult Man | New-born Infant. | Difference. |
|---|---|---|---|
| 3. Cervical Vertebra ... | 10½ Mm. | 6 Mm. | 4½ Mm. |
| 4. " " ... | 11¼ " | 6 " | 5¼ " |
| 5. " " ... | 12 " | 6 " | 6 " |
| 6. " " ... | 12 " | 6 " | 6 " |
| 7. " " ... | 15 " | 6 " | 9 " |
| 1. Dorsal Vertebra ... | 17 " | 6 " | 11 " |
| 2. " " ... | 19 " | 6 " | 13 " |
| 3. " " ... | 21 " | 7 " | 14 " |
| 4. " " ... | 20 " | 8 " | 12 " |
| 5. " " ... | 18 " | 8 " | 10 " |
| 6. " " ... | 19 " | 8 " | 11 " |
| 7. " " ... | 20 " | 8 " | 12 " |
| 8. " " ... | 21 " | 8 " | 13 " |
| 9. " " ... | 21 " | 8 " | 13 " |
| 10. " " ... | 21 " | 8 " | 13 " |
| 11. " " ... | 21 " | 9 " | 12 " |
| 12. " " ... | 21 " | 9 " | 12 " |
| 1. Lumbar Vertebra ... | 22½ " | 9 " | 13½ " |
| 2. " " ... | 27 " | 9½ " | 17½ " |
| 3. " " ... | 27 " | 9½ " | 17½ " |
| 4. " " ... | 28 " | 10 " | 18 " |
| 5. " " ... | 30 " | 10 " | 20 " |

This table again confirms our law. If we except the very small oscillation noticeable between the second and sixth dorsal vertebrae, every vertebra in the table is longer than the one preceding, and shorter than that which follows. The slight oscillation referred to is due to the vertebrae in question being in direct connection with the use of the arms; and I think that I am not mistaken in regarding the tensions and compressions connected therewith as the cause of this increased longitudinal growth of the second, third, and fourth dorsal vertebrae of the spinal column of an adult man. So that in this respect, also, the influence of use and exercise on the grcwth of the bones in question is plainly noticeable.

# XXVII.—DEVELOPMENT OF INFANTS.

## (ANTHROPOGENESIS.)

## (1876.)

THE development of man is the most attractive of the problems connected with the history of descent, and requires, in the first place, an explanation of the difference between the germ-plasma of man and that of other mammals. This is a very difficult question, because chemistry teaches us nothing on the subject, except that man, as well as every other animal species, is characterised by one or more specific odorous matters,* which are doubtless in causal connection with the morphological properties of the individuals to which they belong. I have no doubt that the heredity of many specific characteristics of individuals and varieties is due to these odorous matters, and that there must be a fundamental connection between them and the germ-plasma, *i.e.*, they represent the important factor of organic life which I have described as the animal soul.† To this should be added that the ontogeny of man, in its first stages, is almost entirely unknown. The following are the principal ontogenetic differences known to exist between man and the other mammals :—

First, the development of that part of the neural-fold which afterwards forms the brain. is much more developed in man than in any other mammal.

Second, the hind-pole is very little developed, as compared with the head-pole.‡ If we call this large development of the neural-fold a *megisto-neurula*, we characterise the anthropogenous germ-plasma as a megisto-neuruligenous modification of protoplasm. The first consequence of this megisto-neurulation is, that the circulating system at the head-pole of the embryo is much more developed, and that the enlargement of the arteries in question is considerably greater. This, together with the superior degree of

* See chapter VIII. † See chapter X. ‡ See chapter XIV., page 85.

the growth of embryonal cells, favours the development of the head of the embryo, as compared with other parts. There is, further, the remarkable influence of the force of gravitation, referred to in chapter VI., page 45. The human embryo is distinguished from all other mammals by the fact that, during its whole development, its position is with the head downward. This great physiological advantage is due to the circumstance that the longitudinal axis of the human uterus is more or less perpendicular, while in other mammals it is horizontal. Another factor in connection herewith is, that the uterus of most mammals is tube-shaped, while in the human uterus the longitudinal axis is not much larger than the lateral axis. This allows a much greater adaptability during the earlier stages of embryonal life, with the consequence that, even when the maternal body lies in a horizontal position, the greater development of the head causes the embryo to assume a geocentric position, with the head downward. Of course, in the later stages of embryonal life this is no longer possible, as the embryo has to adapt itself to the dimensions of the uterus ; and we can then only speak of a geocentric position of the head when the position of the maternal body is perpendicular. But even this is a great advantage, as compared with the position of the embryos of most other mammals. There are, of course, exceptions to this rule, as different positions are sometimes adopted by the embryo. But I am of opinion that here, as in many other cases, the exceptions prove the rule ; and I have little doubt that many microcephalic and sub-microcephalic abnormities are due to a more or less unusual position of the embryo. I shall presently prove that these geocentric differentiations do not cease after birth, and that, under their influence, the development of the child continues in a fundamentally different way from that of all other young mammals. The latter retain the horizontal position which characterised them during their fœtal life, while the human infant undergoes two important changes in this respect :—

(1) The geocentric position of the head is changed by the body assuming a horizontal position, which, however, differs from that of all other young mammals.

(2) After the lapse of about a year, the second change is made, to an upright posture, with head erect. In considering the

morphological effects of these two fundamental changes, we shall find the Darwinian doctrine of the greatest practical assistance, as only with its aid can we account for the adoption by infants of the upright posture when they commence to walk. The explanation starts from the zoological fact that children have an instinctive inclination to climb. This is confirmed by the formation of the hand, and of the foot ; the latter, especially, is, from an anatomical point of view, distinctly a rudimentary climbing-organ. The result of this rudimentary development is, that the child, by degrees, learns to stand, and both the foot and the hand are thereby gradually modified.

It may be asked, why, under these circumstances, the upright posture is only adopted after a considerable time has elapsed. Would it not be of advantage to a child to learn to walk at a much earlier period of life ? In reply, we must first consider the circumstances under which a child is born ; and we must then investigate the changes which ensue until the child is able to make its primary efforts to adopt an upright posture.

Every new-born infant closely resembles, in its general morphological structure and appearance, a quadrupedal animal. The arms and legs have almost the same length, and their respective proportions are similar to those of the hind legs and front legs of a dog, or, approximately, as 3 to 2·7. Secondly, both pairs of extremities of a new-born child occupy the same angular position, with reference to the trunk, as is common to all quadrupedal animals, the upper parts of the extremities converging in an acute angle to the axis of the trunk. This position is caused by the doubling-up of the extremities, in consequence of the limited space in the uterus during the last months of pregnancy. Thirdly, the spine shows a similar curvature to that of a four-legged animal. Fourthly, the thorax is compressed in the same way as with most mammals. For these reasons, every one conversant with anatomy will admit that, if a child, almost immediately after birth, had the instinctive faculty of locomotion which many new-born mammals possess, it would not subsequently be able to adopt an upright posture. So that the inability of the human infant, for at least six months after birth, to exercise any power of locomotion (while all other mammals, shortly after birth,

are more or less capable of using their organs of locomotion) is one of the most important physiological factors in the development of the human species.

Let us now consider the changes, together with their causes, to which an infant is subject while still incapable of locomotion. The most important difference between the human species and other mammals in this connection is the normal position of the human infant with reference to the force of gravitation. The infant lies, as a rule, on its back, and consequently the spine becomes more and more straightened, by losing its convex curvature. This effects a gradual change in the position of the legs, the upper parts of which come more and more into rectangular position towards the trunk. So soon as this rectangular position is firmly established, the weight of the legs exercises a further direct influence, with the result that the lower parts of the legs endeavour to find a firm support. So far, only the angles between the trunk and the legs have changed ; but now we notice that the angles between the upper and lower parts of the legs become increasingly altered, until, during the fifth month of life, a fresh obstacle has to be overcome. The legs are now, to a great extent, straightened in the sockets of the loin-joints, but the ligaments will not permit of any further straightening until the girdle of the lumbar bone has changed its position with reference to the spine. This can only be effected by a second curvature of the spine, conversely to the original curvature, which actually happens, the second curvature being due to the pressure of the weight of the legs. By this last process the legs are completely straightened. We thus see that the best preparation for the adoption of the upright posture is to leave the child as long as possible in its first normal position, viz., lying on the back, until it has gradually gone through all the above-described morphological changes. Let us now examine the changes to which the arms and the chest of an infant are subject. At the commencement of life the arms are bent, and rest on the chest, but their own weight soon causes the upper arms to sink down at both sides of the trunk. By this process a tension is exercised on the muscles extending from the thorax to the upper arms ; the thorax changes its wedge-like shape, and becomes more and more flattened. The

chest soon loses the characteristic form of the lower mammals, and assumes the specific human form. After the position of the upper arms has thus changed, the forearms likewise alter their position; as the curvature produced by the elbow-joints continues, they cease to lie on the chest, finding no further support, and their centre of gravity shifts, in consequence, considerably lower down the arms. The effect of these changes is, that the shoulder blades approach each other more and more, and that the collar-bones are subjected to a much greater pressure. About six months after birth, the infant tries to stretch the arms horizontally, when the arms soon adopt a position which no other mammal can imitate, and which, after the child has once become accustomed to it, renders impossible a return to the method of locomotion employed by the quadrupedal mammals. So far, we have established the facts that a new-born infant possesses the general body-form of most of the quadrupedal mammals; but that during the first six months of life these features are gradually lost, with the sole exception of the longitudinal measurements of the extremities, which, however, later on, also attain to proper proportions, after the upright posture has been adopted. As regards this development of the extremities, every new-born child has, more or less, the proportions of the climbing mammals; and it has, as we have seen, not only its hands, but also its feet, developed in the same manner as the *bimana*. Secondly, the first movements of the hands and of the feet of a new-born child are grasping motions, and this is, perhaps, more characteristic in the case of the feet than in that of the hands, the toes being used in the same way as the fingers of the hands. Gradually, however, the mobility of the lower extremities diminishes, and that of the arms increases, because, naturally, so soon as the child begins to play, the hands and arms become of greater physiological importance, in respect of *variety* of motions, than the legs and feet. Thus the upper and lower extremities gradually differentiate, with the resulting characteristic developments. After the body of the child is thus prepared for the adoption of the upright posture, the great importance of a factor which we have previously discussed, viz., the influence of the force of gravitation,* again becomes apparent. Immediately after the

* See chapter XIII.

upright posture is adopted, the lower parts of the body exhibit much more energetic growth than the upper parts ; and I am decidedly of opinion that this important physiological modification is primarily due to the influence of the force of gravitation. I adduce two reasons for this :—

(1) The course of the blood is influenced by the direction of the force of gravitation.

(2) A part of the body which has mechanically to support others must perform considerably more work than parts which are not so tasked ; and, according to *Ranke's* discoveries, the quantity of work performed, or energy developed, is in direct connection with the amount of blood in the part in question.

We thus arrive at the conclusion, that the most important morphological features by which man is distinguished from other mammals, are principally due to the influence of the force of gravitation, *i.e.*, man owes his enormous macrocephalic development * to the peculiar position of the embryo, head downward ; and he owes the characteristic differentiation of his body, and the adoption of the upright posture, to the normal position of lying on the back during the first months of life.

* Compare also chapter VI., page 45.

## XXVIII.—ORIGIN OF THE HUMAN LANGUAGE.

(1867-1870.)

IT has often been held by philologists that investigations on this subject can hardly attain to any definite result. They argue that the beginnings of the human language are so far removed in time from all languages known to us, that it is very doubtful whether we shall ever be in a position to trace the primeval language of man. Yet so fascinating is the problem, that it has been essayed by a number of the first philological authorities, *e.g.*, *Humboldt*, *Herder*, *Grimm*, *Steinthal*, *Max Müller*, and others. *Grimm* considers that the so-called " roots " of the human language are due to the inventive genius of man. This implies that philologists cannot go beyond these roots, which they assume, so to speak, to have been spontaneously generated, a process as difficult to explain as the corresponding one in morphology. A different view is taken by *Humboldt* and *Steinthal*, who consider that the human language is a physiological action, made use of by the human intellect in order to perform certain of its functions. This view is clearly more correct than that of *Grimm*, because it emphasizes the physiological as well as the psychological factor. *Steinthal* goes too far in his explanation of the human and the animal languages, as we must distinguish between the language of animals and the development of the roots of human language ; I am of opinion that these two stages are separated by a long series of transitions, respecting which the above-named philologists give us no serviceable information.

On this problem, which comparative philology has failed to solve, I think that I am able to throw some light, from a totally different source. The Darwinian doctrine includes, as a natural sequence, the assumption that the human species has developed from organisms which differed to a certain extent from their progenitors. How far these organisms differed from the human

species of to-day it is difficult to define; but let us assume, for a moment, that the difference was about the same as that between father and child. If we disregard abnormal individuals, we find that the greatest difference between a new-born infant and an adult is that the adult shows a macrocephalic, and the infant a microcephalic, development of the cranium. Having thus noted the connection between macrocephalic beings and their temporarily microcephalic descendants, we obtain, by help of the fundamental biogenetic law,* a general view of the nature of those beings from whom the human species has developed; they were mammals with macrocephalic crania, and in all probability they were closely related to the present anthropoid apes. Assuming that the parents of the first man were organisms of this kind, we are forced to conclude that the language of primeval man was much more similar to the language of animals than to the human language of to-day. It will therefore be possible, to a certain extent, to discover the nature of the language of primeval man, by investigating the language of the higher animals; and a zoologist who has occupied himself with studying the language of animals is in a much better position to bring forward a theory on the language of primeval man than philologists who merely compare the different human languages. I am aware that philologists may advance the objection that if primeval man spoke in the manner which I have indicated, he was not human, and must be regarded as an animal. To this I can only reply, that investigators who are disinclined to try to bridge over the abyss which separates man from the animals, will reject everything which tends in this direction; it is therefore less the inability to explain, than the unwillingness to investigate, these problems, which prevents the progress of science in this direction. A great difficulty lies in the circumstance that animal language is, as a rule, treated in the most unsystematic and unscientific manner. It appears to me that many comparative philologists have never given serious attention to the language of animals. As a rule, they disregard it altogether, and if occasionally one of them includes animal language within the scope of his investigations, he does not appear to be at home with the subject. But the language of animals is easily understood by anybody who

* See chapter III.

takes the trouble to study it carefully ; every hunter, every biologist, and even every lover of animals, can understand it, without attempting to analyse it scientifically.

It has often been said that animals have no means of communicating their ideas to one another, and that it is therefore difficult to understand the intellectual process by which many actions of the higher animals are regulated. This is, to a certain extent, correct, because animals have no words to express their feelings and thoughts; but just as a mother understands the inarticulate sounds of her child, so it is possible to interpret many of the feelings and thoughts of the higher animals. I will even go further, and say that psychological research regarding the higher animals is, in many respects, easier than when we have to deal with man. Animals possess no language wherewith to hide their thoughts and feelings, while the circle within which they feel and act is narrower, and therefore much more easy to investigate, than the intellectual sphere of man. We are not, however, limited in our investigations to the active and passive behaviour of animals, as many of the more highly developed species have both a language of sounds and of gestures, each being, to a certain extent, as easy to understand as the human language of words. This language of sounds, which many mammals and birds possess, is connected with certain emotions and sentiments, and corresponds to the language of an infant during the first year of its life ; it is composed of more or less characteristic sounds (vowels) or noises (consonants). The interjections of the human language are closely related to these animal expressions of emotion, being, in fact, nothing else than similar sounds in connection with our usual word-language. This becomes evident when we consider the cases in which we commonly employ interjections. The animal uses its language of sounds when the regular course of its feelings is interrupted by emotion, or, psychologically speaking, when the state of indifference changes into that of joy or pain. In such cases, many animals cry, sing, or howl, and, under the influence of similar emotions, man employs interjections. We rarely use interjections while in a state of indifference ; but so soon as we come under the influence of emotion, we not only employ a variety of interjections, but we frequently forget the customary syntactical composition of the language, and use, in the

form of interjections, single words without grammatical connection. In detail, the sound-language of animals has very little in common with the word-language of man. The former, like the language of gesture, is the expression of emotion, and is, so to speak, involuntary, while word-language is the result of intellectual operations. I do not imply that no connection exists between sound-language and word-language; sounds are in many cases the roots of words. For example, the verb "laugh" (German, *lachen*, Greek, *gelao*) originated from a specific sound at the basis of which is the vowel *a* (Italian pronounciation); while the vowel *i* (Italian pronounciation), which is characteristic of restrained laughter, is represented in the English words "giggle" and "titter" (German, *kichern*; Latin, *ridere*; French, *rire*). We thus see how this root enters into various human languages; and the same holds good, not only of many of our own sounds, but also of others which we notice in the organic and inorganic world surrounding us, *e.g.*, the word "hound" (German, *hund*; Greek, *kyon*) is directly connected with the specific sound of the howling of dogs. Even peculiar variations in the sounds of the same species of animals, are represented in various human languages. A good example in this respect is the English word "cuckoo," which represents the usual pairing-call of this bird; while the Greek word *kokkyx* represents a variety, the second syllable of whose call is characterised by a higher sound than the first syllable. The number of sounds which different animals possess varies greatly. Many have only one; but, even then, slight variations can be noticed, according to the kind and degree of the emotion which influences the use of the sound. Singing, which plays such a prominent part in the sound-language, is, in the animal kingdom, an expression of love, and therefore a modification of the pairing-call.

Many animals not only understand the sounds of their own species, but also those of other animals, *e.g.*, the owl knows the whistling of the mouse, and the gazelle the roaring of the lion, &c., &c. But there are also cases in which indirect communications are distinctly noticeable, *i.e.*, the finch understands the swallow's call of fear, and answers with its own; and the blackbird's note of warning suffices to acquaint the deer that the hunter is approaching. Animals which are in direct communication with man soon become

accustomed to certain human sounds which are commonly used in intercourse with them. It is true that this has only been observed in a limited number of animals, but, probably, because very few experiments in this direction have, so far, been made. Not only are single sounds of the human language intelligible to certain animals, but some of the most highly developed domesticated species, *e.g.*, the dog and the horse, learn, if properly trained, to understand and to distinguish a considerable number of words and expressions. I had occasion for several years to observe a very intelligent dog, which afforded me numerous opportunities of experimenting in this direction. This animal not only knew the names of many objects with which it had to do, but it also recognised these names when used in sentences of many words. This was not due to gestures or emphasis, as I proved by many experiments that the dog could not be misled by intentional variations in this respect. If I may be allowed to make the comparison, the intellectual development of this dog corresponded to that of a child of about twelve to eighteen months. As regards the most highly developed animals, viz., the anthropoid apes, I have personally had little experience ; but what we know about chimpanzees and orangs tends to show that their intellect is on a par with that of a child between two and three years old. The faculty of understanding and imitating the human language is well known to be possessed by several kinds of birds : parrots, starlings, ravens, &c., &c. As regards intellect, however, these birds are surpassed by the most highly developed mammals, especially by apes and dogs. This leads me to conclude that the faculty of imitating the human language is not so much connected with the intelligence of the birds, but is rather due to the development of the vocal organs. As a rule, the structure of the vocal organs in mammals is very unfavourable to such imitations, and this is why dogs are, in this respect, inferior to parrots, ravens, &c. As regards the anthropoid apes, especially the orang, this obstacle does not exist, and one would therefore imagine that they could be taught, like parrots, to imitate human words. But we must not forget that the manner in which parrots and other birds speak vastly differs from human speech. The former is only a more or less accurate copy of the sound of the words spoken to them,

and this becomes plain when we compare an untrained parrot with a trained one; while the former cries in its natural voice, the latter tries to imitate, in a similar modulation, what it has heard. Although there are cases in which a bird associates with the words which it speaks certain ideas, *e.g.*, joy or fear, they are very rare; the reason for this may be that, as a rule, the training of parrots is carried on in an utterly senseless way.

Of still greater importance, from a physiological point of view, are the gestures of many animals. The more highly developed animals, capable of performing motions of their own accord, possess a kind of gesture-language. First we have to deal with the facial gestures, which are most developed in the human species, but which are also observed in many mammals and birds; and even reptiles, and other lower animals, have at least one facial gesture of great importance at their disposal, viz., the expression of the eye.

As regards other motions in connection with the gestures of animals, we have to consider gesticulation with the extremities, different kinds of contractions of the body, and, to a certain extent, the changes in colour of the skin noticed, *e.g.*, in frogs, cephalopodes, chamaeleons, and so on. If we more closely investigate the language of gestures, we see that, as in the sound-language, we have here a means of expression adapted to the emotions, but not to the intellectual faculties, of the animals in question. The gesture-language is of the same involuntary nature as the sound-language; and as regards the relation between them, it is necessary to consider gesture-language in connection with the development of the animal kingdom. Psychologists distinguish between two states of feeling: first, that of apathy, which must be regarded as a condition of equilibrium between an animal and its external surroundings; and, second, the state of irritability (characterised by the various affections or emotions), in which this equilibrium is disturbed. If we compare and analyse the different capacities of emotion in the animal kingdom, we observe that, *pari passu* with the decrease in the variety of organisation, the variety of emotions diminishes. While the most highly developed mammals and birds show many of the emotions which characterise man, the lower we descend in the animal kingdom the less we find of susceptibility

to emotion. The first to disappear are the affections and emotions relating to the past and the future; and, finally, only three states of feeling are definitely noticeable, viz., apathy, joy, and pain. But these three states can be observed as low down as in animal groups like the polyps, and, *e.g.*, the actinia provide remarkable evidence in this respect.

It will be seen from the above that many animals have a language of their own; and whoever investigates this interesting problem will find that it is not so difficult as is often imagined, to critically compare the language of animals with that of man. We have to distinguish in the former between the physiological and the psychological elements, *i.e.*, between the sound and what it indicates. In the first stage, the sound is unintentional, being only an involuntary motion. In the second stage, leading to the development of a language, the animal makes intentional use of its faculty to produce sound. The most general element of the animal language is therefore, psychologically considered, a sound indicative of emotion; it does not, however, continue so for any length of time, as the sound cannot remain without relation to the outer world. Every animal which produces a sound will, of course, be heard, thereby indicating to friend and foe its place of sojourn. On the one hand, therefore, the voice of an animal exposes it to certain dangers; on the other hand, the voice is of great value for some of the most important social functions of animal life. As long as such sounds are mere expressions of the emotions of the animal in question, without any reference to the outer world, we cannot describe them as sound-language in the proper sense; for the definition of a language must include its use as a means of communication. The first and principal sound in this respect in the animal kingdom is, as we have previously seen, the pairing-call, and with its appearance the animal language commences. Secondly, hunger, pain, fear, in short, the whole series of joyful or painful emotions, may likewise produce different sounds. The same holds good of all these sounds which indicate emotion, as of the pairing-call, *i.e.*, they acquire a designative significance, thus forming a means of communication which is not merely limited to a particular family or species, but is often understood, as I have previously explained, by quite different species of

animals. It is therefore no exaggeration when I say that many animals speak, and understand one another ; only it must not be forgotten that their language consists of sounds which, psychologically considered, merely indicate emotion. It is highly interesting that a variety of sounds in the human language—chiefly the various interjections—correspond to the animal sounds.

A further point of importance is, whether there exists in the animal world another kind of communication by sound, representing a further progress in the foundation of a language. This is actually the case, but only under very exceptional circumstances. I refer to the imitation of the singing and voices of other birds by, among indigenous birds, the linnet (*Sylvia hypolais*), and several kinds of shrikes (*Lanius*) ; further, there is the American mocking bird (*Turdus polyglottus*). What is the physiological explanation of this imitation of sounds of other birds? It is well known that, in many instances, certain sounds induce human beings, as well as animals, to use their own vocal organs. For example, canary birds often commence to sing, and parrots to cry, when an animated conversation takes place in the same room ; moreover, birds disinclined to sing do so when a bird which readily sings is brought into their vicinity ; nightingales sing so soon as their specific call is imitated, and so on. The physiological explanation, therefore, of the imitation referred to above is, that we have to deal with a so-called synkesis of the voluntary motions. When a sound has once been adopted, it soon becomes the expression of a certain emotion, caused by a certain action, or a certain object ; and thus it is made a means of communication. We have here a second element in the language of animals, viz., the *onomatopœia*, which plays the same part in the language of animals as in that of man, *i.e.*, the organism is named according to the sound which it is capable of producing. I have now enumerated all the features which characterise the language of animals, and the results may be summed up as follows :—The sound-language of animals consists of interjections and *onomatopies*, the former being the more important, and the principal of them being the pairing-call ; the *onomatopies* are only met with in a very limited number of birds, physically and psychically highly developed.

If we now compare these facts with the human language, we have first to consider that, according to *Darwin*, man has gradually raised and separated himself from the animal world. But in this connection it is important to remember that the anthropoid apes, which are anatomically and psychologically most nearly related to human beings, are almost without any sound-language. A few sounds, induced only by strong affections and passions, are the sole language of communication which these animals possess. The gap, however, is somewhat lessened by the circumstance that the gesture-language of the anthropoid apes is very highly developed.

In reply to the question whether this great difference between man and the ape has any corresponding examples in the animal kingdom, I point out that the onomatopoetic talent is not less individual among species of birds. For instance, the carrion-crow (*corvus corone*) and the raven (*corvus corax*) are very similar in respect of body and intellect : and although, anatomically, the resemblance between them is much closer than that between man and the ape, we know that the raven has the onomatopoetic gift, while the carrion-crow is without it. There is a similar difference between the mimic-thrush and the other species of thrushes ; and the parrots form another analogous group in this respect. Proceeding a step further, we may say : the human language originated so soon as a microcephalic species of anthropoid apes commenced to vary in the direction of macrocephalic development, thereby growing in intelligence, and evolving a certain amount of onomatopoetic talent, which the species became sufficiently intelligent to use as a means of communication with other individuals of the same kind. Those who are of opinion that the parrot's faculty of speech is of no great scientific importance, point out, as an important difference from human beings, that a parrot only learns what it is taught, and that, so far, no kind of parrots has been produced which can speak without being taught. My reply is that the human child, also, can only make use of word-language after having learned it. This is proved by the fact that children who are born deaf remain dumb ; and the well-known experiments of some Asiatic despots, who caused children to grow up without being taught any language, show that individuals who can hear are yet unable to speak a word-language unless they have learned it.

To this I would add, that the kinds of parrots which have been taught to speak, do not breed in captivity, and are consequently precluded from transmitting this faculty. But if it should become possible to domesticate and breed some of these parrots, I have little doubt that the result would be a variety capable of using, to a certain extent, the words which they have been taught, as a means of communication between themselves. Moreover, the need of communicating with each other to a larger extent is only felt by animals which lead a social life, all other animals having, as a rule, no other means of communication than the pairing-call. But animals which remain with their young ones for a longer period of time soon develop a second element of language, viz., the summoning-call of the mother ; and, ultimately, a number of other calls may appear, whereby the individuals composing a flock communicate with one another. The sound-language is therefore a direct result of the need of communication among animals of social instincts. The same holds good of the human language, and we all know that practical need decides in many instances whether a sound or word is retained by the memory. How many things are afterwards forgotten over which we have spent much time at school, but of which we make no practical use in after life !

This leads me to the principal factor in the development of language. Every language is, as *Steinthal* correctly remarks, not simply a physiological function, but also depends, to a great extent, on the development of the psychical faculties. The number of words which a person uses in daily life stand in direct relation to the more or less many-sided development of his intellect ; and, regarded from this point of view, the fact that so few sounds suffice for communication between the higher animals is simply a consequence of their much more limited intellectual sphere. In order to accurately proportion the relation of the human to the animal language, it would first be necessary to discuss the relation of the human to the animal spheres of intellect. This leads us to ask why, if the evolution of language is in direct relation to the development of the psychical faculties, such highly intelligent animals as the anthropoid apes are almost without any language ; and why all attempts to teach them some human words have

failed. To this I reply: first, how is it that deaf and dumb persons, who have been taught a sort of sound-language, make no use of it when they are among themselves, but prefer to communicate with one another by means of their natural gesture-language? The answer is, that this gesture-language suffices for their wants, and that the sound-language is of no advantage to them, as deaf persons only notice the motions of the mouth, which are not nearly so good a means of communication as the much more pronounced gesture-language. Comparing this fact with the means of communication of the apes, we find that their pronounced gesture-language, together with some specific calls, is quite adequate for them as a means of communication.

My second question is: why cannot many human beings be taught singing? They are neither deaf, nor is their larynx abnormally developed; but they do not possess what is called musical talent. Why should not corresponding differences exist between various animals? In this connection I refer to the fact that the raven can be taught to speak, while the carrion-crow cannot. The answer in this, as in all analogous cases, is, that intellectual development and practical need are not the sole factors in the problem, but that a third must be added, viz., a certain onomatopoetical, or musical, talent.

Athough I have only dealt with the most prominent features of our subject, we see how many circumstances have to be considered, if we wish to explain the origin of the human language. I have shown that many of these factors depend upon the inclination and talent, apart from the morphological position, of the individual. Most probably, the human language has developed from the animal language, and the difference between them to-day affords no ground for assuming that man is of different origin from the rest of the organic world.

Let us now examine into the nature of the language of primeval man. If we assume that the animal progenitors of the human species were not endowed with a superior language to that of the best-developed apes, we must inquire how the first nucleus of the human word-language was formed. We have seen that anthropoid apes have a very pronounced gesture-language, and, in addition, a small number of sounds for the expression of pain, passion, joy,

and terror, as well as some characteristic pairing-calls. I have already dealt with this rudimentary sound-language of the higher apes, and I will now discuss their gesture-language somewhat more in detail. In its inception, this gesture-language is merely indicative of emotion, corresponding to the sound-language. In the next stage, it acquires a designative significance, in the sense which I explained when dealing with sound-language. So soon as a located object becomes the impulse to a communication between the animals in question, the gesture indicates (by the direction of the eye, and by the motions of the whole body) the presence of this object. Thus the action of pointing is developed in the anthropoid apes to great perfection, and its importance lies in the fact, that the pointing of the ape is in many respects identical with that of man, as anyone who has observed an ape will confirm. The primeval language of man commenced when his intelligence had so far grown that he found means to communicate concerning *absent* objects. For this purpose pointing alone no longer sufficed, and the question is, how was a new means of communication created? Our only means of dealing with distant objects are the senses of sight, hearing, and smell. The sense of sight gives us the form, the sense of hearing the sound, and the sense of smell certain chemical impressions of an object. So soon as the intellect of an organism is sufficiently developed, it will try to create means of communication respecting absent objects through the impressions produced by these three senses.

Both the senses of smell and of sight induce gestures of minor moment; but we find that the sense of hearing exercises a direct and important influence on the functions of the vocal organs. I have previously said that the organs of hearing and the vocal organs are in close physiological relation to one another, and, naturally, the ear regulates the voice. A similar physiological relation exists between eye and hand—the eye regulates the motion of the hand. The influence of the organs of these senses on the voluntary motions is further noticeable with regard to involuntary motions, and, therefore, also, in the case of the synkinesies; and I have previously shown that the imitation of sounds is a synkinesy.

Summing up, we find that when the sounds and gestures which indicate emotion no longer sufficed for the needs of communication between individuals of a social nature, designative gestures were evolved ; the eye was assisted by another organ with which it is physiologically closely connected, and thus objects which were present to the view were designated by pointing. Further, so soon as the need arose to find means of communication concerning *absent* objects, the sense of hearing came into play, and was assisted by the vocal organ, which is physiologically connected with it ; thus the voice came to be employed for the purpose indicated. It follows from this explanation, that the development of the primeval language of man cannot be understood without taking into consideration the gesture-language of the most highly developed animals. At the remote period in which the human language originated, sound-language was much less independent of gesture-language than are the highly developed forms of speech of to-day, as both sound and gesture form integral parts of the same means of communication. I point out, however, that in the intercourse of savage tribes gestures still play almost as important a part as words. *Greenhill*, *e.g.*, reports that, near Cape Palmas, in Africa, a tribe exists whose language is unintelligible, unless supplemented by the necessary gestures. Such observations give us an idea of the primeval language of man ; no doubt, it was a combination of sounds and gestures indicating emotion, of designative gestures, and of various kinds of calls.

Our next question is : was there more than one primeval language? In reply we must remember that during these earliest times of civilization this primeval language must have been split up into dialects to an infinitely greater extent than when regular communication came to be established. The manifold diversities in the language of the South American savages at the present day confirm this view. The development of a language is always in direct relation to the degree of intercourse between large numbers of individuals. Wherever intercourse is restricted, dialects are apt to be formed. But, it may be asked, if primeval language consisted of sounds of emotion, and of imitations of natural sounds, how could it be split up into dialects ? To this I reply that individual notions are perhaps more arbitrary in respect of

interjections than of any other element of the sound-languages of civilized nations. We have only one explanation for this, viz., that we attach very little importance in the languages of to day to the interjections, because they have lost their significance, in the same way as have the gestures. But at that remote time, when gestures and interjections were the most important means of communication, both were, no doubt, used in the same way as deaf and dumb persons now use gestures. We must not forget that there was then nothing to lead men to form large communities in constant intercourse with one another by means of language. It is sufficient for savage nations when the individuals of a tribe understand one another; and thus it was possible, from the very outset, for an immense variety of sounds expressing emotion, and of sounds of imitation, to develop. This was the more easy, as we cannot assume that, during the first millenia of its existence, the human race formed one single large community.

Nothing, however, is more difficult to imitate than natural sounds. As I have occupied myself with the study of the imitation of animal sounds, I can speak from personal experience; and in many cases I have found it impossible to imitate such sounds without the use of the hands and arms, or of artificial devices. No doubt, the imitation of sounds was one of the most important processes in the formation of the human language. Until the sounds of imitation were formed, primeval man, or his progenitors, only possessed sounds of emotion; but so soon as he sought to transform natural sounds into the language at his disposal, he was obliged to modify his own sounds of emotion, and thus sounds corresponding with certain of our alphabetical letters began to be formed. When these came to be voluntarily produced, there was no further limit to development than that imposed by the growth of intellect and by practical need. Moreover, we must not forget that absolutely correct imitation is only necessary if we want, *e.g.*, to decoy a bird by means of its specific call; for the purpose of conversation even a poor imitation suffices, and thus the development of a multiplicity of languages was quite natural. This tendency to diversity was assisted by the fact that many animals are capable of producing a variety of sounds. For example, the peacock can emit two different sounds, viz., the deep

nasal *pao* and the high *tai*; and it happens that the Indo-Germanic nations named the peacock after the former, while the Chinese named it after the latter. The reproduction of clearly-articulated natural sounds would be the same everywhere, because the original sound could always be heard, and the reproduction would continue to be recognised as a direct imitation of it. But whenever the imitation was more difficult, there resulted a number of variations in the words which were founded on it. We can therefore say that, just as certainly as the human species had one origin, human speech is derived from one single primeval language. But the latter was, of necessity, soon split up into a variety of modifications, which became so well defined that, except some interjections and sounds of imitation, the only remnants which exist of this primeval language are the alphabetical constituents; and, as everybody knows, even these are not all common property, and cannot be pronounced by every nation and race. Therefore, to find the elements of this primeval language, we must try to discover a scale of categories of words, and I have commenced to arrange such a scale, beginning with the sounds of emotion, followed by those of imitation.

In the following remarks I will try to show that the sounds of emotion were the first, and the sounds of imitation the second, element in the development of the human language, my views on which are confirmed by an analogous series of stages in the development of language in the individual. The first sounds which an infant produces are merely sounds of emotion, and, du·ing the first weeks of life, have not even the significance of a means of communication. According to my experience, it is during the fourth week of life that the infant commences to make intentional use of sounds, by crying for food. The second sound of emotion noticeable in an infant corresponds to a feeling of pleasure, connected with the gesture of laughing; on the other hand, the call for food is produced by a feeling of pain. The sound of laughing, however, occurs much later, viz., at the beginning of the fourth month of life. The next months are characterised by the division of the sounds into various expressions of joy and pain, which differ in importance. For instance, the child has originally only one cry in order to express hunger as well as pain; but

during the third month the mother can easily distinguish from the sounds whether the child is hungry or whether it suffers from pain. A very important modification is noticeable in the sounds of pleasure, and here we observe the influence of imitation, as children are wont to laugh when the mother laughs. It is only during the last quarter of the first year, however, that the child acquires the faculty of making proper sounds and imitations. During the first month of life the sounds and the gestures of emotion are quite isolated ; but in the second and third months the child commences to grasp ; and before the imitation of sound begins, the process of pointing is completely developed.

When we closely investigate the child's imitation of sounds, we perceive the great importance of practical needs in the formation of language. The child first imitates the sounds which it hears from the mother, and for a long time remains indifferent to everything else. It is not, however, the child who has the practical intelligence, but the mother, who educates the child ; while, in the historic development of the species, the outer world plays the part of the teacher, whereby the practical need is developed in the pupil. In both cases we have the same process of development before us. It is not theory, but practice, which decides what is to be taught and learned. The child's first imitation of sounds represents, and is analogous to, the primeval language of man. It is only after the lapse of the first two or three years of life that a child is able to use its vocal organs so as to form the sounds of the letters of our alphabet. When the imitation of sounds commences, viz., at the end of the first year, the child can only use vowels, and more especially the "*A*" and the "*O*," together with the labial and soft lingual consonants. All other sounds the child omits, or substitutes its own sounds for them. The result is, that the development of the language of the individual shows the same stages as the language of animals and men, viz., first we have sounds of emotion, afterwards gestures, and finally the imitation of sounds. This view of the development of the human language is further supported by the fact that the gesture-language seems to follow the same course of development as that of the sound-language, beginning with gestures of emotion corresponding to

the development of the individual, as well as of the species, followed by the gestures of pointing, and, finally, by gestures of imitation.

Secondly, I am of opinion that the modification of the human gesture-language which exists independently of the sound-language, viz., the gesture-language of deaf and dumb persons, as well as those modifications of which savage tribes make use as a sort of universal language, are a more or less accurate counterpart of the primeval language of man. The most important circumstance in this respect is, that gesture-language develops whenever other means of communication are wanting, and that it is always the same. We know of three different centres of human gesture-languages, viz., first, the American Indians ; second, deaf and dumb persons ; and third, the Cistercian monks of the middle ages, several of whose gesture-languages have been traced. In all these cases the means of communication are so identical that deaf and dumb Europeans of different nations can understand each other without much difficulty ; and the secret languages of the Cistercians only differ in a few respects from those of the other two gesture-languages. This strong coincidence is a proof that the human gesture-language is not an arbitrary invention, but the result of physiological and psychological processes which always act in the same direction, if a means of communication with the assistance of gestures is required, as was the case with primeval man ; and it is evident that similar physiological and psychological processes must have yielded a similar result.* The question is now, what constituted these gesture-languages ? Their two most important elements were the gestures of emotion and of pointing. As I have previously explained, the primeval language was a systematic combination of sounds and gestures of emotion, as well as of gestures of pointing. After man had recognized that the element of sound in language is a better means of communication than the element of gesture, the former was increasingly developed, and thus the more practical sound-language naturally superseded the gesture-language to some extent. In the same measure, therefore,

* Compare the interesting reports on the intercourse between Indians and civilised deaf and dumb persons given by *Romanes;* see also *Darwin* and *Fritz Schultze.*

as the sound-language developed, gesture-language was neglected, and it has remained in the same state as when it formed an integral part of man's primeval language. It is true that gesture-language again became of practical importance as a universal means of communication ; but this necessarily involved its remaining more or less in its original state, while in the course of development of sound-language differences naturally ensued. These considerations render it very probable that the gesture-language of savage tribes, as well as of deaf and dumb persons, is not only a close reproduction, but that it is nothing less than the mimic remnant of the primeval language of men, with the addition of a number of gestures which have subsequently been added to it in place of the sounds of emotion and some other factors which belonged to the primeval language. We shall therefore be able, to some extent, to reconstruct this primeval language of mankind, if we substitute for gestures of emotion certain sounds of emotion.

A third important point is, that the connection between man and animal is still much more apparent in gesture-language than in sound-language. If the manner in which the first men communicated among themselves was a development of the method of communication between the higher animals, and if it is correct that gesture-language even now represents the primeval state of this method of communication, it is clear that the human gesture-language is much more closely related than the human sound-language to the language of animals. This is proved by the fact that almost all gestures of emotion are the same for man and animals, *e.g.*, quailing with fear, starting back in terror, staring in astonishment, protruding the lips as a sign of desire, and many other gestures.

We have now exhausted, from a zoological point of view, the different factors which give us an idea of the origin of the human language ; but I am well aware that we have still to consider a number of phases of development before we arrive at the point where comparative philology, starting from the other end, was compelled to stop, viz., the origin and development of the so-called roots of the different human languages. Until this gap is bridged over, zoologists and comparative philologists will find

difficulty in joining hands, and the latter will object that, so long as the roots are not explained, the chief problem remains unsolved.

According to my view, the sounds of emotion represent the first linguistic development of mankind, and by disintegrating them, later on, the alphabet was formed, enabling man to produce onomatopoetical combinations. I believe that this view leads directly to the explanation of at least some of the roots of languages. Certain of these roots have the significance of sounds of emotions, others that of sounds of imitation, while some originated by transmuting the impressions of the other senses into impressions of the sense of hearing. We have therefore, in the last-named category, to deal with impressions of the senses of sight, smell, and taste. This is, of course, a very difficult subject, but I will try to show by one example what I mean. The word to stand (German, *stehen*; Latin, *stare*; Greek, *histemi*), has, in my opinion, as its original root, the peculiar calling-sound "*st*"; and the result may have been that the *effect* which this calling-sound produced, viz., the bringing an individual to a standstill, was expressed by the calling-sound itself. I do not attach great importance to this example, and I may be mistaken in this more or less hypothetical explanation; but what I want to convey and to explain is, that if comparative philology is further developed, many sounds of emotion and of imitation will doubtless be capable of explanation in the manner indicated.

I should like to emphasise in this connection again, that however these developments may have taken place, the principal factor in the formation of the elements of the human language was *practical need*. We have to deal with the impressions of the senses which were the cause and the basis of the formation of words. On these impressions the gesture-language of to-day is founded, and so was the human sound-language, at a time when man had only *material* needs and wants. Perhaps in no other branch of science has the ignoring of the natural conditions in respect of the mode of living led to greater misapprehension than in comparative philology. I believe that the line of research which I indicate in this chapter will bring considerable fruit, so soon as investigators endeavour to study in detail the languages,

customs, and intellectual wants of those tribes and nations whose circumstances and conditions are nearest to the primeval state of mankind.

According to Professor *Max Müller*, the Sanskrit group of languages has not more than 121 different roots, and the gesture-language of the natives of America has not more than about 150 expressions, which suffice for all practical needs of conversation. We cannot assume that primeval man required better means of communication than the Indians of to-day. Therefore, if my view of the primeval human language is correct, viz., that it was made up of a systematic combination of gestures and sounds, the figure 150 represents both elements (words and gestures); and this leads me to conclude that about 100 words amply sufficed for the primeval vocabulary of man.

At the beginning of his well-known work on the origin of language, Professor *Max Müller* cites *D. Stewart*, who is of opinion that if we investigate the history of mankind, and cannot discover the exact circumstances to which an occurrence is due, it is often of importance to be able to show how such occurrences may have been produced by natural causes. He further thinks that, although it is impossible to indicate with certainty the ways and degrees which characterize the development of a language, yet so soon as we are able to determine how the different parts of a language might have developed, according to the well-known principles which govern human nature, not only shall we gain a certain amount of intellectual satisfaction, but a check will be imposed on the indolence of thought which takes refuge in explanations founded on a supernatural basis. This view will be welcome to all investigators of natural science, because it shows that the theory of the supernatural is now as much abandoned in anthropology as in zoology; and that the adherents of the doctrine of descent have no longer to encounter prejudice, when they try, as I have done in this chapter, to explain development in this branch of science. *Max Müller* himself, in the course of his investigations, criticises the various theories on the origin of the human language; and the gist of his criticism is, that it cannot be denied that a language might have been formed according to the principle of imitation. But he asserts that, so far, we have not been able to discover any

language which has been formed exclusively on this principle ; and that the same holds good for the theory of interjections.

I agree with this view, for I have good reason to believe that no human language has ever been formed according to strict rules and principles, but that, on the contrary, language is the result of natural and practical needs and wants. Moreover, to argue that a language can have developed either from sounds of imitation or from interjections alone is as little justified as to discuss, *e.g.*, the question whether gunpowder consists only of coal or of sulphur. It is surprising that *Max Müller* stopped short in his criticism, and did not draw the conclusion that wherever one of the elements (1. sounds of imitation, and 2. interjections) is not an adequate explanation, the problem may be solved by combining the two. *Max Müller* asks how sound can become the expression of the thoughts, and answers by saying that several hundreds of the roots of the human language are neither interjections nor imitations of sounds, but phonetic types. These types, according to *Max Müller*, are produced by a certain force, inherent in human nature ; and he believes that man, in his perfect primeval state, was able to give articulate expression to the intelligent conceptions of his mind. But he adds that man did not himself develop this faculty ; it was, in his opinion, an instinct of the human intellect, as deeply implanted as every other instinct.

I can hardly imagine a more negative explanation. Are not the sounds of emotion likewise phonetic types, produced by a force inherent in man ? And is not this whole argument a phrase without meaning ? Had *Max Müller* said that the endeavour to trace the origin of the human language had failed to penetrate beyond the roots, no polemical discussion would be possible ; but by his assertions which I have just quoted he actually arrests the progress of science in a manner which I venture to think quite inadmissible. In trying to discover the origin of the human language on a different basis to that of the supernatural, it must be borne in mind (1) that the primeval language of man was a so-called natural language, similar to the sound- and to the gesture-languages of the savages and of deaf and dumb persons ; and (2) that the human languages of to-day represent a further development of the primeval language, certain elements of which they

still retain. Whoever firmly adheres to these principles, will find, I believe, that there is no alternative solution of the origin of the human language to that which I have adopted in this chapter, *i.e.*, the roots disintegrated by the philologists must be reduced to the following elements :—

(1) Sounds of emotion,
(2) Sounds of imitation ; and,
(3) Symbolic facial gestures.

Reverting to the simile previously employed, we may compare these three factors with the three materials of which gunpowder is composed, viz., sulphur, coal, and saltpetre. It might be objected that the above theory implies the presence of certain roots, not only in the Indo-Germanic group, but in all human languages ; and this is correct, although these roots will not be found in all cases to possess the same significance and the same sound.

It is as certain that the sounds of laughter (of which we have previously spoken) are not the same with all nations, as that several nations, *e.g.*, the Hottentots, have letters which we Europeans cannot even pronounce. Some roots may be common to different nations, but they are not always *equal*. As regards the significance of gestures, the different gesture-languages teach us that the same gesture can assume two totally different meanings, one or both of which are, of course, secondarily developed ; and the same must be the case with the roots of the sound-language ; for there can be no doubt that, long before the fixing of these roots, the geographical expansion of the human species on the globe was so considerable that a uniform and conventional fixing of these roots is inconceivable. On the contrary, we must assume a number of different centres of origin for the human word-languages. To ascertain this number should be one of the principal objects of comparative philology.

*Bleek*, in his well-known investigations on the origin of language, has chiefly dealt with the comparative investigations of South African languages. To this subject *Bleek* devoted nearly twenty years, and, as *Haeckel* remarks, he had special talents for dealing with this fundamental anthropological problem. The results at which *Bleek* arrived are, that the words of human language entered upon the first phase of their existence when the sounds of

emotion were no longer produced in a purely arbitrary sense. The second phase was when, through use and habit, the sounds became more firmly established as conventional means of communicating the emotions which they indicated. The third phase commenced when it was occasionally necessary to express emotions which were not precisely described by a complex of sounds; but which, at the same time, were equally near to two such complexes. The most natural thing in such cases was to let one of the two complexes of sounds follow the other. *Bleek* adds that, on the one hand, in certain emotions the word could represent the immediate effect exercised by the organs; on the other hand, imitation was induced of those sounds which were most striking to the sense of hearing. Both the sounds of emotion and of imitation are voluntary expressions of feeling; they can therefore be treated together when we deal with the origin of words, for everything which has been said about the sounds of emotion will equally apply to the sounds of imitation.

So far *Bleek*. All that he writes on the sounds of imitation is in complete accordance with my own investigations on the value of imitation in forming the human language. In harmony with *Bleek*, I have come to the conclusion that we have first to deal with sounds of emotion, and then with sounds of imitation.

As regards the relation of *Bleek's* researches to my own, I have to remark that his views are not in opposition to those propounded by me, but form a valuable addition to them. On the other hand, I should like to emphasise that he does not deal with the subject before us in the same manner as I do, especially as regards the pairing-call, and the relations of sound-language to gesture-language. It would be a valuable addition to our present knowledge, if the South African, or other savage languages, could be subjected to a careful examination with reference to the points which I have indicated. *Bleek* has not exactly shown where the human language separates from the animal language. He has correctly discovered the main features of the development of the human language, but, in my opinion, he goes too far back in the direction of the animal kingdom.

I think that I have proved that the human language commenced at the time when a species of mammals came into

existence, which inherited a higher degree of intelligence from its progenitors, and, adopting a social life, transmitted certain processes of imitation, not only in respect of gestures, but also of sounds. Thus, language, in its proper sense, had come into existence long before the human species, a fact which is evident from the observation that all pairing-calls are language, pure and proper; but the human language only commenced after the anthropoid apes had developed a sound-language.

Observations of children show that, previous to the development of language, an aphonic period exists, almost exclusively devoted to receptivity. Quite analogously, the anthropoid apes are aphonic to a surprising degree, while, at the same time, their receptivity is highly developed. These are the factors which would be needed in order to produce the present wealth of language, which commenced to accumulate so soon as the tongue of a highly developed mammal was loosened.

# PART III.

# VARIA.

## XXIX.—SPIRIT AND INTELLECT.

(1884 and 1885.)

IT is easy, by observations of ourselves as well as of others, to classify the so-called intellectual functions of the human mind, which we may describe as *feeling*, *will*, and *imagination*, but it is exceedingly difficult to solve the problem of their cause and nature.

Admitting our inability to explain these functions, we find that the subject is altogether ignored in text-books of physiology, and that speculations concerning the human intellect are abandoned to students of philosophy and religion. This appears to me to be wrong, because every living being is a *uniform* organism, which we must fail to understand as a whole if physiological research ignores so important a factor.

We have to consider two points of view—the material, according to which the will, feeling, and imagination are the functions of the material substrata of the brain, and the spiritual, which ascribes them to a peculiar immaterial *agens*, in no way connected with the organs of the body. Every scientist who really studies the laws of nature is compelled to join in this controversy ; but it is one of the chief drawbacks of modern science that most investigations are carried on by specialists, with the result that each of them understands certain details, while nobody comprehends nature as a whole. The scientist who tries to investigate the functions of the human mind must also be able to recognise the factor which governs it. In examining these functions we have to deal with two factors :—(1) impressions of memory, which embrace a great variety of qualitatively different objects ; and (2) a factor which is ordinative over this variety, and represents an indivisible unity which I call the *ego*.

I.—*Impressions of Memory*.—Natural science has recorded a great many investigations respecting this factor, and experiments

and observations have established the relations between the impressions of memory and the corporeal substratum, with the following result :—

1. The impressions of memory have their seat in the outer layer of the great brain.

2. They occupy certain spaces, separated according to the nerves of the different senses, through whose functions of irritability they have been brought together and stored up. The investigation of these spheres of memory has owed most to the interesting experiments of *H. Munk.*

3. All impressions of memory require a certain space in the brain. This has been proved, not only by instituting comparisons among various animals, but also by the experiments of human physiology ; and it has been shown that the total sum of impressions of memory which an organism is capable of retaining, is in direct proportion to the development of the surface of the brain. Concerning this development we have to consider, first, the absolute size of the brain, and second, the intensity of the windings of its surface.

Impressions of memory are made by the action of our senses, or of our will. They are therefore induced by the irritability of certain nerves ; and the more frequently the spaces of the brain in question are affected by repeated acts of irritability, the more permanent the impressions of memory become. In the production of these impressions by the influence of the senses, the following factors are important :—

1. So soon as the irritability of a sense affects, by way of reflex actions, the motoric conductivities and the muscles in connection therewith, we see that the impression of memory which remains is much slighter than when no reflex actions take place. As a consequence, periodic rest of the body is of great influence on the functions of the memory.

2. The impressions are more pronounced in proportion as we concentrate our attention on them.

3. The intensity of the impressions is subject to great specific and individual variations, and is also affected by the number of times that the impressions are repeated, either by the senses themselves or by the influence of the *ego*. It is a well-known

fact that impressions of memory which have not been brought before the mind for a considerable period may completely disappear.

4. The impressions are not confluent, but are subject to the laws of isolation, although certain connections exist between the isolated centres.

5. There are two different conditions of the memory, viz., that of rest, in which impressions are not apparent to us, and that of activity, during which these impressions are brought into relation with the *ego*, as well as with other impressions of the memory.

6. The action by which memory becomes present to the *ego* is called "thought"; but this term includes everything which comes before the mind, just as we use the word "recollection," not only for the act of recollecting, but also to signify whatever we remember.

As regards the connections which exist between the impressions of memory themselves, we have to deal with the following laws :—

First, there is a natural connection between impressions formed simultaneously; these are more closely connected, and are more easily recalled, than impressions formed at different times.

Second, there is the law of sequence, *e.g.*, as thunder follows lightning; thus in many cases the recollection of one thing leads to the recollection of another.

Third, the law of similarity. If a new object is seen, it is only in exceptional cases impressed upon the memory without relation to other facts. As a rule, an act of comparison takes place, connecting the already stored-up impressions of memory with the new object.

Fourth, the law of contrast. It is not easy to explain this law, but if we consider that contrast becomes in many cases a connecting link, *e.g.*, day and night, heat and cold, we can see that an organism may use its reflectoric means of defence against strong irritation, just as the eye protects itself against a blinding light by automatically contracting its muscles. Another physiological explanation of the law of contrast is illustrated by the connection in the mind between great fatigue and the subsequent pleasant feeling of rest; thus the law of contrast is practically the same as

that of sequence, named above. We can subdivide the four laws mentioned into two groups:—(1) those which act simultaneously, and (2) those which act in sequence.

The natural connection between these two laws of memory may be influenced by the activity of the *ego*. This is especially the case with man as compared with animals; for the following reasons:—

1. Man possesses the advantage of a well-developed language, which allows him to connect a certain number of single memories by means of sound. Thus the so-called *conceptions* are formed, and, generally speaking, the formation of a conception follows the natural connection of the impressions of memory. On this natural basis we can create a scale of more general conceptions, fixed by words, and, moreover, there is the utmost freedom for variations, because the human language affords the necessary connection. The conditions of the impressions of memory which result from linguistic abstractions are termed "logical."

2. The second difference consists in the fact that man, on account of his largely-developed brain, can store up impressions of memory to a much greater extent than any animal.

3. The conditions of existence of man, especially in a state of culture, are much more diversified than those of the most highly developed animals. The result is, that the few natural connections between the very limited material of impressions of memory which animals possess are used as often as possible, and become more and more customary and habitual, a state of things whereby the difficulty of connecting new combinations is much increased. We may therefore define the difference between the animal and human intellect, with regard to the functional relations of the impressions of memory, as follows:—An animal's process of thinking consists in a customary association of its conceptions. Man, on the other hand is able to think logically, *i.e.*, to form conceptions, judgments, conclusions, and so on.

II.—*The Ego.*—In examining this most important intellectual factor, I purpose to first ascertain the basis on which it is founded, by considering the actions which characterise it. I will add a description of the objects to which the activity of the *ego* refers, and of the functions of the *ego*.

1. The Fundamental Basis of the *Ego*.—The chief difficulty here is to explain the intellectual functions. In investigating the nature of the *ego*, we first see that we have to deal with an absolute unity, and not with a plurality, as in the case of the impressions of memory. This is shown by observations of the state of mind which we call "attention." Here we have two antagonistic conditions, viz., those of concentration and of distraction of mind. Directly the latter condition commences to change into the former, we notice a so-called centre of concentration, which is characterised by the fact that only one such centre can exist at a time. The functions of "attention" can only be compared to the functions of electricity; but all efforts to find a ponderable substratum of the intellect have, so far, failed.

We arrive at the same negative result if we regard the intellectual functions as peculiar motions, either of ponderable matter or of ether. The motions of matter are either mass-motions or molecular, the characteristics of which have long been explained by physical investigations; but none of these investigations would even approximately explain the motions which characterise the human intellect. Therefore, in the same way as we sometimes speak of a fourth, unknown state of aggregation, it will be convenient to speak of a third, unknown form of motion. But these unknown motions, like the unknown state of aggregation, are entirely hypothetical, if we do not regard both as originating from a "separate actuality." This shows that we have to regard the *ego* as such a "separate actuality," viz., as "spirit," expanded over the whole grey cortical substance of the brain, which can concentrate and dilate in such a way that there seems good ground for believing that the materials of the impressions of memory are located in intellectual spheres round isolated ganglia cells. With the aid of this conception we gain an insight into the organisation of the spirit, by separating it into (1) the division of impressions of memory, which consists of a number of co-ordinate elements, and (2) the *ego* division, which represents a unity capable of absolutely free motions.

Finally, I will refer to the position of the factor termed the "soul." Many trichotomists treat the soul and its functions as being of transcendental nature. I have refuted this view in a

previous chapter,* and have shown that the exact laws which govern the functions of the souls of the various organisms are beginning to be recognised. That the intellect is wholly independent of the soul will be evident to anyone who compares the functions of the two, and the laws which govern those functions.

2. The principal objects of the activity of the *ego* are threefold :—(1) All motions within the human body. Those, however, connected with the cerebro-spinal nerve-centre and its branches are in direct relation to the *ego*; while motions connected with the vasomotoric and vegetative parts of the nervous system are only in exceptional cases direct objects of the *ego*. The motions in question are therefore (*a*) the irritations of the senses ; (*b*) the voluntary motions, and (*c*) those reflex motions which belong to the voluntary apparatus. (2) The division of the impressions of memory (see above). (3) The *ego* itself, which may also be regarded as an object, *i.e.*, not only the *ego* pure and simple, but also the changes to which the *ego* is subject under the influence of the soul, as well as all activity which the *ego* exercises.

3. The functions of the *ego* are, of course, either active or passive. The former are those in which the *ego* transfers the results of its activity to the outer world, *i.e.*, enters on the so-called "motoric phase" ; the latter are those in which the spirit derives its incentives to activity, and we may properly term this the "sensitive phase." But the activity of the spirit has a third phase, which, again, may be sub-divided into two branches :—(1) the connection between the active and the passive phases, and (2) the activity of the spirit, without reference to any particular direction. I will take the latter first, and here we have to consider two different points :—One is "attention," the effects of which are two kinds of motion of the *ego*, the first being a change between the state of distraction and that of concentration ; as regards the latter state, we have to distinguish between the centre of concentration, in which all forces of the *ego* find their maximum development, and the peripheric parts from which "attention" is distracted ; the second motion of the *ego* is the change in locality

* See chapter X.

of this centre of concentration. The other point is the state of feeling of the *ego*. Here we have first to distinguish between the different degrees of irritability of the *ego*, which move up and down a scale, at one end of which we notice the state of waking, and at the other that of sleeping; during the latter state the irritability of the *ego* is at its lowest, and the oscillation between these different stages takes place according to the laws of fatigue and recreation. Secondly, in the waking state, with which we are here principally concerned, we first notice a contrast of rest and motion, and then two different motions—a quantitative difference, *i.e.*, slow and quick motions (slow and quick intellect), and a qualitative, rhythmic motion, which represents intellectual joy or pleasure, as contrasted with the non-rhythmic motions of intellectual pain.

We will now discuss the "sequences" of states of the intellect, caused by its relations with different objects.

Sequences of the different states of attention may be of a passive or active nature. As regards the former, we have to consider the accuracy of perception and consciousness; and as regards the latter, the intensity and precision of the resulting actions, the velocity with which they are performed, and the accuracy with which the connections take place. If the attention is in a state of concentration, we have to deal with a contrast between the active and passive processes which develop themselves in the centre of attention, and the processes which take place where the attention is distracted.

This contrast is greater in proportion as the attention is concentrated on one point and distracted from another. As regards single acts, if the centre of attention is directed to a reflex motion, the retardations, as well as the accelerations, of the reflexes are more prompt and definite; while when such centres of attention are absent, the reflex represents an involuntary act, with a velocity corresponding to the conductivity in question. If the centre of attention is directed to the beginning of a motion, as, for instance, to the sphere of a sensual nerve, smaller incentives suffice to produce consciousness than are necessary when the attention is distracted. Regarded from the active point of view, we find that voluntary actions which take place under the direct influence

of the centre of attention are performed quickly, and in the proper tempo ; but when the attention is distracted, the actions are performed more slowly, and without the necessary amount of energy and circumspection. The same holds good for all connecting activities ; while in the centre of attention, the latter are performed quickly, but when the mind is absent, they are either not performed at all, or are retarded, or they are performed in a wrong direction and with inadequate energy.

In the state of distraction of the *ego*, the contrasts just described do not exist ; and all functions (the active and passive, as well as the connecting ones) are performed with mediocre rapidity and energy.

As regards the sequences of various states of collective feeling of the intellect, we have first to consider that, when we sleep, relations between the *ego* and its objects are either impossible, or are only possible if the motions by means of which the objects act upon the mind are exceptionally strong. As a general rule, every sleeping organism is a reflex machine without consciousness or will. The relation of the mind to its objects only becomes apparent in a state of waking, but this relation greatly varies according to the general feeling of the mind when awake. For instance, in a state of joyful emotion all external activities of the mind are quickly and easily performed, only an adequate amount of strength being required ; while in a state of pain all activity is either retarded by obstacles, or by taking a wrong direction, or by quantitative inconveniences, or by inaccuracies. This is especially noticeable when an individual flies into a passion ; the irregularity, and the oscillation between extremes, are very apparent.

As regards the causes which produce changes in the state of the intellect, every concentration of the attention is either the sequence of a spontaneous act of the *ego*, or is caused by an external incentive. With respect to the production of the various general feelings, two circumstances have to be considered :—

1. The spirit is influenced by the soul, because the former passively participates in all processes which are in connection with the soul, and all motions of the soul are communicated to the spirit in a corresponding way.

2. Independently of the soul, the spirit can produce similar states of motion, by means of the motions connected with the process of

thinking. These are the so-called "self-feelings" of the intellect, or the purely spiritual feelings. Directly connected with them are the moral and æsthetic feelings, which, as purely intellectual feelings, have to be distinguished from the variations of the state of the intellect, due to the participation of the spirit in the motions of the soul. I have still to describe the processes which result from the fact that the objects of the activity of the *ego* are of a variable nature.

*a.* With reference to irritability, general feelings, and reflexes, the *ego* is perceptive; it observes, registers, and judges. All these actions, taken together, are termed *perceptions*.

*b.* As regards the reflex apparatus, as shown in the voluntary actions, which are, however, limited in such a way that the *ego* can only directly act on the cerebro-spinal reflex apparatus, the *ego* may be active, the result being the will.

*c.* As regards the objects represented by the impressions of memory, the *ego* is either passive, *i.e.*, it observes, or active, *i.e.*, it wills. This activity, directed to the objects of memory, is the process of thinking, during which the *ego* has before it a series of impressions of memory. This causes a change of the centre of activity, which follows certain routes, determined by a number of well-established laws, corresponding on the whole to the connections which, as I have above explained, exist between the impressions of memory, viz., the laws of simultaneity, sequence, similarity, and contrast. This phase of thinking is termed association of the perceptions, provided that we have to do with impressions of memory which are of a concrete nature. With man, these thinking operations are much more complicated than with even the most highly developed animals, because all human impressions of memory exist in a double sense, viz. (1) concrete, and (2) linguistic. Language has enabled man not only to fix each impression of memory by a word, but also to connect a plurality of impressions by means of a single word. From this follows the faculty of logical thinking, which may also be explained thus: association of the perceptions is practical thinking, while association of words is theoretical thinking (logical thinking).

From these causes originate the great differences between the animal and human intellect. The animal cannot reason like man,

for reason consists in the influence of logical thinking on concrete thinking, *i.e.*, logical thinking controls and affects the association of perceptions. This form of intellectual activity is entirely wanting in the animal kingdom, because the animals are without the "logos," which term correctly indicates, not only "the word," but also reason, as reasoning is impossible without a word-language. Moreover, man has self-consciousness, which the animal is without. The *ego* can only be its own object (see above) when it has a concrete existence and an existence represented by a word; this word must be of such a character, and its importance is so great, as to represent the sum of all the experiences of the *ego*. The act which leads to self-consciousness is, in my opinion, to be thought as follows: the concrete *ego*, which is always a subjective entity, summons before its mind the whole of the material comprised in the word in question. This material is composed of all the experiences which dwell in the memory of the *ego*, and of all the words connected therewith. No doubt, an animal has also certain perceptions of experiences which it has made in respect of its *ego*; but as animals are without the word *ego*, their experiences are *disjecta membra*; while, on the other hand, by the word *ego* man connects his experiences into a unity.

As regards the process of thinking, we have first to consider the sum total of the impressions of memory. The greater this total, the more varied will be the possibility of new connections between the impressions.

I will now discuss the co-operation of the different constituents of an organism (spirit, soul, and body):—

1. The reflex mechanisms of the body depend in many respects, as regards *quale* and *quantum*, on the actions of the soul. As the body consists of numerous and different reflex mechanisms, which are of a specific nature, it follows that they are not all influenced in the same way by one action of the soul, but that the relative conditions of irritability are subject to various changes. If the spirit does not exercise its influence (as in the state of absent-mindedness), the organism is a reflex machine, subject only to the influence of the soul. This, for instance, is the condition of a man while asleep, and of an animal which is without the cortical substance of the brain. But if the spirit is acting, it can either impede or

accelerate external reflexes, or can give another direction to them; in short, the *ego* performs the functions of directing the reflexes. It follows that if, by the activity of the *ego*, the functions of a reflex are accelerated, this reflex acquires the character of being involuntary, and it takes little or no part in the functions of memory and imagination. But if the *ego* impedes the functions of a reflex, the irritability is communicated, in a greater degree, to the single centres of memory, the result being that a process of thinking commences, which is defined as "deliberation." It depends on the results of deliberation whether the motion intended by the reflex is carried out; in these cases we speak of deliberate activity or inactivity. Such actions are distinguished from the involuntary ones by a somewhat retarded execution, because to the time which a reflex requires must be added the time necessary for the deliberation. Whether the spirit is able to initiate and to execute acts of will entirely of itself, without any external cause, is difficult to decide; for the external cause of voluntary actions may be so weak, and the operation of thinking connected therewith so occult, that we are often subsequently unaware that any such cause existed, and believe ourselves to have acted entirely on our own initiative. However this may be, it is certain that external causes are more necessary to animals than to man, and their actions, as regards intensity and direction, are much more dependent than man's on these external causes. This is easily intelligible, because animals associate external causes with comparatively few impressions of memory, while the least external cause may produce a very pronounced activity of the thinking operations of man. Thus the difference between man and the animals, as regards their actions, results from the disparity in number of the ways of communication and connection.

2. Under certain conditions the relative functions of the three constituents (spirit, soul, and body) are disturbed or altered. Such conditions exist when we sleep, but here we have to distinguish several cases:—

When the body sleeps and the spirit is active, we have the condition of *dreaming*. In a waking state the impressions of the senses preponderate over those of the memory; while when we dream, the latter prevail, and in this state the relations between

the impressions of memory and the consciousness acquire the same intensity as the impressions of the senses during our waking state, *i.e.*, they produce the impression of actual objects. Whether there is sleep without dreaming is a question which has been much discussed; we often awake with no recollection of having dreamed, but whether this is actually dreamless sleep cannot be decided.

Finally, I would say a few words, in connection with these problems, and from the point of view of natural science, on the momentous question of immortality. Mortality, *i.e.*, transitoriness, is due to changes in the state of aggregation, to changes in chemical synthesis, and to decomposition of ponderable matters. The spirit, on the other hand, suffers no change in the state of aggregation, or in a chemical sense, and this great difference between spirit and ponderable matter is correctly defined as immortality.

# XXX.—DARWINISM AND RELIGION.*

(1869.)

AT a recent International Congress of Scientists, the celebrated Physiologist, Professor *Helmholtz*, suggested that the Congress would afford a good opportunity to ascertain the progress which the Darwinian doctrine had made, how far it was recognized by men of science, and to what extent it was still opposed. *Helmholtz* stated that he did not make this suggestion in a polemical spirit, but merely on statistical grounds. The idea was taken up, with the result that not a single scientist raised his voice against the Darwinian theory. After this verdict, it might be deemed superfluous to treat the matter any longer in a controversial spirit. But one objection to the Darwinian doctrine is still raised by its adversaries, and greatly influences many minds, viz., Darwinism is said to be opposed to religion and morality. I have therefore thought it necessary to institute investigations on this point; and, although I have not studied theology, I have had so many discussions with theologists on the subject that I hope to explain my views in a scientifically satisfactory manner.

Stress has been laid upon two points, in order to influence public opinion against the Darwinian doctrine. The first is the well-

* It is interesting to note that in this chapter, written as early as 1869, *Dr. Jaeger* has, in many respects, anticipated the important researches which *Mr. B. Kidd* published not long ago in his well-known work on "*Social Evolution*." To show the connection between the views of *Jaeger* and *Kidd*, I add two passages of *Kidd's* work (edition of 1895), viz.:—

Chapter V., p. 112—*Definition of a Religion*—A religion is a form of belief, providing an ultra-rational sanction for that large class of conduct in the individual where his interests and the interests of the social organism are antagonistic, and by which the former are rendered subordinate to the latter in the general interests of the evolution which the race is undergoing. We have here the principle at the base of all religions.

Chapter V., p. 126—In the religious beliefs of mankind we have not simply a class of phenomena peculiar to the childhood of the race. We have therein apparently the characteristic feature of our social evolution.—The Ed.

known dictum that, according to *Darwin*, man has descended from the ape. Let us assume, by way of comparison, that a writer on the history of our country and of our ancestors records that the latter were unwashed savages, who passed their time in lying on bear skins, intoxicating themselves with mead. If he went on to say that we, ourselves, are scarcely better than our ancestors, we should correctly describe him as ill-mannered. But if a historian not only explained that our ancestors were tribes of hunters, but also showed how they gradually raised themselves to the high level of our present civilisation ; and if he pointed out the means by which we can further advance, we should call him a teacher of the human race. Exactly the same applies to the Darwinian doctrine. If a Darwinian used his knowledge for no other purpose than to sneer at his fellow men as descendants of monkeys, we should call his conduct in question. But mankind is benefited if, by the light of the doctrine of descent, the influences are investigated under which our race has gradually risen from a low animal condition to its present level of culture, and the human intellect has developed to such an extent as to be capable of that highest of studies, the laws of nature. Moreover, such investigations lead to the acquisition of new and important knowledge, and serve to indicate in what way our descendants may attain to still higher physical and intellectual development than we enjoy. Thus we have the means, not only to improve the individual, but also the whole species.

Turning, now, to the second objection which has often been made to the Darwinian theory—that it is opposed to religion and morality—we have to consider two questions, viz., what, according to the Darwinian theory, is the position of man with reference to nature, and what is his position towards his fellow men ? As regards the first question, it is evident that each animal species is autonomous, and armed in the struggle for existence solely for the purpose of self-defence ; further, each species can only exist by enhancing as much as possible its means of opposition to all external influences which may injure it. The supreme law in this respect is, therefore, that of self-preservation and of self-defence ; and only one point of view in this respect is possible, viz., the egocentric law, according to which man is the centre of the whole

creation. The gist of this law is expressed by the commandment in the Old Testament :

" Be fruitful, and multiply, and replenish the earth, and subdue it."—Genesis i., 28.

The Darwinian theory recognizes this commandment as a formulation of the highest law of nature for all organic beings ; and it must be admitted that the exigencies of the doctrine of descent could hardly have been expressed in a more precise and practical manner. Only prejudice can assert that the Darwinian theory tends to degrade mankind to the level of the animals, and seeks to minimise the difference between the present human race and its animal ancestors. The reverse is the case : *Darwin* has discovered the law of nature which enables man to attain to a higher degree of perfection, and to widen the gap which separates the human species from the lower organisms. As regards the position of men towards each other, the Darwinian doctrine enables us to investigate by objective means the influence of various conditions of existence, and the importance of these conditions in the self-defence of the species.

As social intercourse is such a prominent feature of man's existence, the first question is, whether a social or a solitary life is more to the advantage of the human individual. Sportsmen know the difficulty of taking by surprise animals which live in herds or flocks, because hundreds of eyes protect the community. Sociability has always been one of the best means of successful attack and defence. The Darwinian theory is in harmony with the principle of sociability, and especially with that kind of social intercourse which has been adopted by human beings. The most important weapon of man in the struggle for existence, viz., his intelligence, is a product of his social habits. The basis of human society is the family, and it is interesting to note how animals which live in families are distinguished from those which leave their young ones to their fate. We shall find that the former are characterised by a much higher development of the means of communication, and by a much more complete organization of the expressions (gestures, language, &c.), connected therewith. Solitary animals have usually, so far as language is concerned, only the pairing call ; while the language of animals which are sociable,

and care for their young ones, abounds with calls intended to attract and to warn. Closely connected with these facts is the relative degree of intelligence, as is natural ; for, in order to rear their young, the male parents must possess considerable cunning and artifice, as well as the use of various instruments of defence I have always admired the high degree of skill to which animals may raise themselves in this respect.

The family, which is the basis of society, originated through the young ones, after they had grown up, remaining with their parents, thus forming the nucleus of a flock or herd. Such a community has a great advantage in the struggle for existence ; but in considering the development of intelligence, we must distinguish between two forms of society, one of which greatly assists, while the other retards it. I will call the first of these the *organized*, and the other the *communistic*, modification of social life. In the latter case only those advantages are found which directly depend on the intercourse of many individuals, associated for the purposes of attack or defence. But this association relieves each member of a communistic society of a part of his duties, and the direct consequence is a decrease in the energy of self-defence. The organized form of society is very different, and here we have only to deal with the principle of division of labour, which is the most favourable for the development of animal, as well as vegetable, organisms, for the following reasons :—The organization of a well-developed animal, or vegetable, body is based on the fact that groups of individual cells unite, in order to provide the *cell-state* with instruments useful in the struggle for existence. Some groups of cells devote themselves to the function of nutrition, others to that of perception, others to locomotion, &c., &c. It is plain that the greater the number of such instruments for defence and attack, the stronger will be the community. What holds good for a single organism is equally true for a society of individuals. As a typical instance of social organization in the animal world, we cannot do better than select the ants : these minute insects have marvellously developed their community ; they are devoted to agricultural and pastoral pursuits, which they followed long before man tilled the ground, or domesticated animals. In addition to the development of instruments of attack and defence,

an organized community is strengthened by the fact that the principle of division of labour accommodates itself to the various individual tendencies. In a community where only one kind of work is required, the number of individual variations useful in the struggle for existence would be limited, and consequently all other variations would disappear. But where there is division of labour, each suitable variation finds a sphere of activity in which it may be useful to the community, at the same time carrying out its individual purpose. Hence, within a short period of time, such a community may contain and support a maximum number of different individuals. Next in importance ranks the influence which an organized community exercises on the development of the individuals and of their families. The following main points should be noted : the more limited the sphere of an individual's occupation becomes, the more perfect will be his development within this special sphere. A one-sided development is, of course, open to certain objections ; but the great advantage of a proper division of labour is that new opportunities of occupation are constantly discovered, and that competition exercises a stimulating influence. The better a society is developed in respect of individual members, the greater will be the number of different occupations. In addition to the benefits which proper organization confers on the society *in toto*, and to its effect in raising the active and the intellectual powers of most of the members, the individual struggle for existence is rendered easier. On the one hand, each member enjoys a greater amount of personal liberty, as compared with solitary individuals, *i.e.*, each can select from a number of occupations that which is best suited to his tastes and abilities. Moreover, the individual's energy need not be scattered over multifarious occupations, because division of labour results in every one working, not only for himself, but also for others. It is important that there should be periods when each one may rest from the struggle for existence, and enjoy his life ; and this alone has enabled civilized man to develop the science, art, poetry, music, &c., which distinguish him from the uncivilized savage.

Summing up, we owe everything that we are, know, and do to the circumstance that we live and move in a society organized on the principle of division of labour. Therefore, if

a Darwinian is asked what man's position should be towards his fellow men, he will reply that the supreme law of human life is :—

"Thou shalt love thy neighbour as thyself" (Leviticus xix., 15.) This is the foundation of all social progress, and no other struggle for existence than that which results in the division of labour can be allowed within the community. *Darwin's* definition of the struggle for existence by no means recommended the introduction of lawlessness. The struggle is unlimited, so far as the surrounding natural conditions are concerned; but as regards competition between man and man, it must be absolutely limited by the laws of social life, the first of which is to love our fellow men. The position of a Darwinian with reference to the social question may therefore be thus defined :—He supports the principle of division of labour; he aims at the consolidation of the ties of family, which are the foundation of our social life; he does battle for the community against the selfishness of the individual; he places the common weal higher than the prosperity of any single member; and he requires each individual to exert his faculties as much as possible for the direct advantage of the community, which can only exist in the long run if its members are developed to the highest possible degree of perfection.

I think that I have succeeded in showing the absurdity of the statement that the Darwinian doctrine is a danger to order and morality. Let us now turn to *religion*, and consider how far it develops and holds together our social life, and to what extent it improves and perfects the faculties of the individual. We Darwinians need not join in doctrinal disputes, nor need we discuss whether this or that religious dogma can stand its ground against scientific criticism. We simply investigate the part which religion fills as an instrument in the struggle for existence, and how far religion accords with the highest law of organic nature, viz., that of self-preservation. We have to distinguish in this respect between two groups of religions, one founded on the relations of man to nature, and the other on the relations of man to his fellow men. The former group comprises the so-called natural religions, which originated in the endeavour of man to explain the causes of natural phenomena. The lowest degree of

these natural religions is represented by Fetishism, which is founded on a variety of imagined causes, without any sensible connection. The second step was to connect these ideas as to causes with the simplest elements of nature, *i.e.*, with fire, water, earth, and air. These are the natural religions in which the visible forces of nature are worshipped. The recognition of other causes, to which these visible forces are subject, led to the conception of personified gods, as we find them in the mythologies of the ancient Egyptians, Greeks, Romans, &c., as well as of the old Teutonic races. But the force of abstract reasoning could not be stayed at this point in the *investigatio causarum ;* behind these personified gods it sought a yet higher force, and thus arrived at the definition of an ultimate cause: Polytheism transformed itself into Monotheism. Hence, the "All-father" of the Teutonic races, the Moira of the Greeks, and the Fatum of the Romans. Nor was this the final stage of religious development ; as philosophers found it impossible to penetrate the mystery further, many of them rejected the whole system, becoming Atheists, and thus the highest development of natural religion, viz., that of the ancient Greeks, came to an end.

Inquiring into the practical worth of these natural religions, we note that the search for God in nature was undertaken with the aid of only one human faculty, viz., philosophical reasoning. The result was a great amount of intellectual speculation, to which we owe the various philosophical systems of the ancient Greeks, regarded to this day with the greatest admiration. It might have been thought that natural religion would have led to the development of natural science, as both have the same ultimate object, viz., the investigation of the causes of the external world. But the secrets of nature cannot be discovered by mere philosophical speculation ; they can only be learned by slow and exact empirical research, supervised and guided by the reasoning of the intellect. Thus natural science could only develop after the *ethical* religions had imbued the race with moral force, earnest desire for truth, and tenacity of faith, without which aids no success in solving problems of this kind is possible. A great defect, inherent to all natural religions, was that they afforded no guidance in the important question of the relation of man to man. They did not prevent the splitting-up of society into political parties, and philosophical

schools, which gave rise to much internecine strife, and destroyed the political energy of the community, opening the door to external foes. Thus we read that the Greek States and their philosophical schools perished so soon as, in the struggle for existence, they were opposed by fresh political factors and forces.

Turning now to the ethical religions, we at once see that they are based on the relations of man to his fellow men. The lowest type of these religions is the so-called *cult of the ancestors* ; and from this it was only a step to the cults of tribes or nations. To illustrate this, let us take the highest development of monotheistic religions in ancient times, viz., the cult of the Jews. Their God is the national God of the Israelites, the representative of law and order, under whose guidance the Jewish nation fought its battles as no other nation of the world has done before or since. What this form of religion, this conception of a monotheistic God, was capable of accomplishing, can only be understood by a close study of the history of the Jewish nation. Nowhere in the classical literature of the Greeks and Romans do we find such endurance and energy in the struggle for existence as in the history of the Jews, under the guidance of their monotheistic God. The demands which the Darwinian doctrine makes on every form of religion are much better fulfilled by the Jewish religion than by all the philosophical systems and natural religions which are guided by abstract reasoning. It is true that the Jews politically succumbed in the unequal struggle against the Roman colossus ; but the ancient Greeks and Romans have disappeared, while the Jewish race remains as a factor of great importance. The force which ultimately overthrew the Roman Empire was the Christian religion, built on the foundation of the Jewish faith ; and the whirlwind of the people's migration had no difficulty in completing the destruction. The importance of the socialistic patriarchial idea of a God was again forcibly illustrated when Mohammed endeavoured to form an empire which, at one time, threatened to subdue the whole civilized world. The strength of Mohammedanism, as compared with the Jewish religion, is that the former is tolerant where other nations (as distinct from other religions) are concerned, while the ancient Jews separated themselves from all communion with the heathen. The Mohammedan religion was thus more

suited to form a great state; but it could not flourish in the long run, like a properly *organized* state, because it was based on the principle of fatalism, which practically amounts to the abandonment, more or less, of self-defence.

It is an axiom, needing no further proof, that the Christian religion could only have developed out of the monotheistic Jewish religion; and if, at some future time, another religion should revolutionize the world, it could only be the outcome of Christianity. No critical authority can believe that either Mohammedanism or Buddhism will be capable of reaping the fruits of our occidental civilisation. The reason of the enormous progress made by Christianity, as compared with the slow development of the Jewish religion, is seen in the commandment which the founder of Christianity inculcated as the first and most important, viz.:—To love God and one's fellow men. As regards the love of man for his fellow men, we must remember that the organization of the old Jewish community, or nation, was split up into tribes, houses, families, and so on; and in many respects the law limited the intercourse between these various sections of the nation A great advance was achieved when the Christian religion abolished these tribal limits and obstacles, causing the whole Jewish genealogical organization to collapse. Christianity made the individual free; and this freedom is in perfect harmony with the Darwinian law of individual variation, as it implies the important natural principle, that division of labour is necessary for every social development. Moreover, the preaching of this law put an end to the exclusiveness which for many centuries separated the Jews from the surrounding nations. The monotheistic religion was no longer the property of one single state or nation, but became a factor of world-wide influence. Thus mere objective considerations, supported by practical experience, show that every religion is an instrument of use in the struggle for existence, and that the Christian religion, as compared with all other creeds, is by far the best instrument in this respect. A convinced Darwinian will therefore neither be Mohammedan nor Buddhist, but will firmly defend the Christian faith.

We will now deal with a subject of the highest importance in the Christian religion—*the doctrine of immortality*—which did not

form part of the old religion of the Jews, although we find traces of it in the period immediately anterior to the Christian era. Christianity alone gave to this doctrine its definite form, and its high importance as a complement of the law to love one another. When the organization of the old Jewish community was broken up, and so soon as each individual became free in matters of religion, there was great danger that this equality might result in the communistic form of society of which I have before spoken. We know that the first Christian societies were communistic; but this tendency was arrested so soon as each individual had to defend his own property. By property I do not mean in this case worldly goods, because Christianity required from its adherents that every one should in the first line protect, under all circumstances, his moral and intellectual possessions. In this way Christian society became organized, and one of the most influential factors of this organisation, from the very outset, was the doctrine of immortality. It required of each member of the society that he should at all times care for his moral and intellectual being, and submit his actions to the control of the intellect, *i.e.*, that they should be in accordance with the laws of Christian morality. The doctrine of human immortality greatly widened the gap between man and the animals, and man was thereby proclaimed to be absolutely distinct from the rest of the organic world. But this doctrine was of still more importance for the organization and development of human society. As each member of the social organism must, in due course, be removed from it by death, there is a danger that many might refuse to fulfil their duty to society, on the ground that death is the ultimate goal of individual life. But whoever believes that death is not the final end of existence, will recognise the obligation to shape his actions with due regard to his hopes of eternal happiness, and of his being called upon at some time to render an account.

Thus the doctrine of the life hereafter is of great practical utility in establishing society upon a firm basis; because whatever a man does during his life, whether on material or intellectual grounds, must, more or less, influence the society, and if his action is contrary to the society's interest, it may endanger its existence. We can therefore definitely say that the doctrine of immortality is an

immense influence for good from a moral, as well as from a social, point of view. Moreover, every community is compelled, under certain circumstances, to demand sacrifices from its members. We know by observation that ants, bees, and other insects, as well as human beings, and even the cells of our own bodies, must be prepared to die, in order to serve the community. A doctrine which increases readiness to sacrifice individual interests to those of the community must be of the greatest advantage to the latter. What would be said if, at the time of an epidemic, our physicians thought only of their own safety, and left the sick to their fate? What would be said if our scientists, guided by the instinct of self-preservation, refused to undertake the necessary investigations of the causes of infectious diseases? Sacrifices are necessary in all phases of human existence, and when society requires its members must be prepared to die. In this connection I ask again: can anything be simpler, more practical, and more capable of universal application than the doctrine of immortality, in order to inspire the members of a community with the courage of self-sacrifice? It might be argued that intellectual or philosophical reasoning would show to a member of a community the necessity of serving it, under certain circumstances, by the sacrifice of his life. But such abstract, philosophical reasoning cannot be looked for from the majority of men, to whom the question is not one of intellect, but mainly of feeling. A moral law is required, which must take deep root in the minds of the young, because later in life it is difficult, if not impossible, to implant it. Children cannot be impressed with abstract, philosophical ideas and doctrines; and this equally applies to one half of the adult human race, viz.—the female sex. I say this in no disparaging sense; preponderance of feeling makes woman the loving companion of man, and the loving mother of children. Every religion must reckon with these feelings, which are deeply rooted in our human society; and no abstract teaching, therefore, can take the place of the doctrine of immortality. Moreover, this doctrine is in close connection with the personification of religion, *i.e.*, with the doctrine of a personal God, which wins its way into the mind of the mother and the heart of the child, both of whom are guided by personal feelings, but in no way by philosophical abstractions. Going to the

root of the Christian religion, viz., the question of *faith*, I would ask anyone, be he scientist, or statesman, or trader, whether he can dispense with faith in its most general sense. Confidence and faith, by sustaining the energy of the scientist and his belief in his ultimate success, enable him to carry on his most difficult researches. Confidence and faith give to the statesman courage to face all dangers ; and without confidence and faith no trader would show enterprise in business. Whoever wants faith is a fatalist, without energy or enterprise, and his fatalism will, sooner or later, prove disastrous to him. In all conditions of human existence faith is as the arm which wields the sword in the battle of life, and this idea underlies the Christian faith. In proof thereof I cannot do better than quote a passage from the New Testament, which is equally characteristic of the original conception of the Christian faith, and of its connection with the fundamental laws of organic nature :—

> "And what shall I more say? For the time would fail me to tell of Gideon, and of Barak, and of Samson, and of Jephthae ; of David, also of Samuel and of the prophets, who, through faith, subdued kingdoms, wrought righteousness, obtained promises, stopped the mouths of lions, quenched the violence of fire, escaped the edge of the sword, out of weakness were made strong, waxed valiant in fight, turned to flight the armies of the aliens."—Hebrews xi., 32-34.

Nothing could more clearly show the original meaning of Christian faith ; and we Darwinians are right in saying that such a faith is a valuable weapon in the battle of life to every one who holds it. If the Christian religion places this faith under the direct protection of an Almighty God, who will blame? In face of the danger of selfishness, which threatens every community and every individual, it must be our constant endeavour to give the highest possible authority to all laws which may not be violated with impunity.

I think that I have said enough to show how untenable is the assertion that the Darwinian theory is opposed to the Christian religion. But I go further. Until now, science and theology have not been able to come to a mutual, straightforward understanding. I am convinced, however, that so soon as both parties abandon dogmatic speculations, and try to meet *on the practical ground of our daily life*, they can easily be reconciled. The cause of the unhappy

differences between theology and science lies in the fact that natural science has but one means of arriving at its goal—the senses, and but one instrument which it can use—the intellect. These two factors can only deal with matters which are subject to direct observation ; and with all things not so subject natural science (as such) can have no concern. This must be our point of view in dealing with transcendental, philosophical, and theological questions. The scientist founds his observations on the fact that the basis of the intellect is brain-power. But this does not imply that there is no God. When the person of the Deity is invoked, in order to interfere with scientific investigation, scientists are compelled to make a stand, and to disregard any factor of arbitrary irregularity. We only seek for the *truth*, and every scientist knows that so long as all the forces of nature have not been discovered and explained, our investigations are incomplete. The action of theologians in calling upon science, in the name of the Deity, to cease her investigations, was therefore very ill-advised, first, because science will not cease to investigate, and, second, because the proper conception of the Deity was thereby exposed to unnecessary and inadequate critical treatment. On the other hand, some scientists have been guilty of excess in attacking the idea of a Deity. Every unprejudiced observer must admit that there is a shrine where the conception of the Deity may have full reverence accorded to it—the shrine of our own inward feelings and experience.

I know that it is an unthankful office to step between two antagonists, and to say :—both of you are wrong, your differences are chiefly due to misunderstanding. But in face of the fact that this difference between theology and science has in the past been disastrous for both parties, it appears to me that it is the duty of every seeker after truth to try to come to an understanding by which the dangers of indifferentism, immorality, and fatalism may be averted ; and by which both parties may be brought to see that, so long as the strife endures, neither of them can be a true teacher of mankind. I believe that I have proved the Darwinian doctrine to be in no way opposed to morality and religion ; and I conclude by saying that there is only one truth, and that whoever seeks for it earnestly will find it.

## XXXI.—THE CONFIGURATION OF THE ARCTIC REGIONS.

(1865-1869.)

THE geographical distribution of living organisms was raised by *Humboldt* to a separate and important branch of science, which has since passed through several stages. *Humboldt* himself dealt with it as a statistical matter, but the progress of geology and palæontology, as well as of zoology and botany, has caused it to be treated historically; and the present recognition of its importance is chiefly due to *Darwin's* investigations. The geography of animals and plants is closely connected with the historical development of the surface of the earth, by which alone the migrations and isolations of organisms can be explained, and the problems of the geographical distribution of animals and plants be solved. The most noteworthy fact appears to be that the Northern Hemisphere plays a much more important part than the Southern in the history of the animal kingdom. It is usual to attribute this to the greater surface of the continents in the Northern Hemisphere, and to the variations in the coast-lines of the continents which have either been ascertained, or are hypothetically assumed, to exist. Such is the view which *Darwin* takes in his investigations on this highly important subject, but it is not an adequate explanation. To the question why the North Pole is a geographical centre of living organisms, we are prompted to add an inquiry as to the geological processes which are the reason that the history of the two poles has been so different in this respect. The causes of the unequal distribution of land between the Northern and Southern Hemispheres cannot be directly explained, because we have not sufficient geological details. We are, however, enabled to arrive at certain conclusions in this direction by the well-ascertained and important fact of the *removal of masses of land from the poles.*

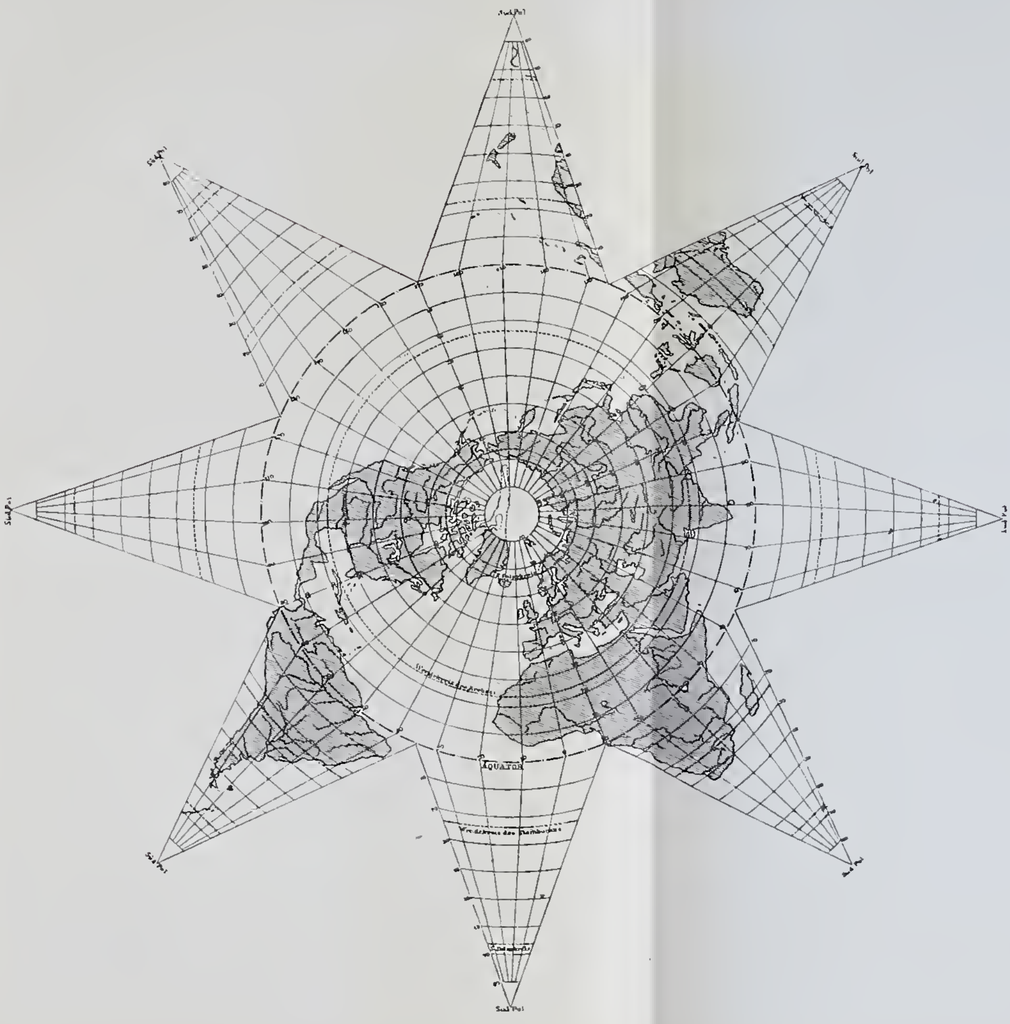
It is not only a common observation, but one of great geological significance in connection with the researches respecting the so-called glacial period of our planet, that large masses of land are carried from one place to another by the many icebergs which are annually dispersed from the Arctic Regions. This transportation of land always takes place towards the equator, for the simple reason that the sea-currents have, like the atmosphere, a kind of circulating motion, because the warmer water flows towards the pole, and the colder water towards the equator. These currents either flow side by side or one above the other. Naturally, coasts surrounded by warm equatorial currents are free from glaciers, which are only found on coasts touched by the cold Polar currents. Consequently, the glaciers and icebergs which break away are always carried from the poles in the direction of the equator. Our next question, therefore, is whether this loss of material is recouped by the transport of solid masses in the opposite direction ; and it might be assumed that the equatorial currents convey alluvial matter from the large tropical rivers in the direction of the poles. But, apart from the fact that this would hardly be a sufficient compensation for the land removed by ice, the equatorial currents are not strong enough to prevent the gradual sinking of the alluvial matter, which consequently comes within the influence of the cold Polar currents, beneath the equatorial currents, and is carried back again towards the equator. There can thus be no compensation for the enormous masses of earth which are constantly removed from the poles. The result of this whole procedure is therefore a removal of land in the Polar regions, accompanied by a deepening of the Polar seas, and a corresponding increase of land in the direction of the equator. Comparing the Northern with the Southern Hemisphere, we see that this procedure was probably more effective in the latter, and that the increase in the land took place nearer to the equator than could be the case in the Northern Hemisphere. If we seek for the cause of this inequality, we shall find that on the Northern Hemisphere the principal mountain ranges of the old world run in the direction of the parallel circles of latitude. The mountain ranges of eastern and western America form a triangle, opening to the north ; in the Southern Hemisphere the principal mountain ranges run in the direction of the meridians. I am aware that

natural science no longer regards the mountain ranges as being, so to speak, the backbone of the continents, for we know that the upheaval of the principal mountains took place after the formation of large masses of *terra firma*. But I am of opinion that the general trend of the mountain ranges indicates the direction in which the continents first made their appearance. If we assume that, in the earlier geological ages, flat chains of islands were arranged in a similar direction to that of the mountains of to-day, it is clear that these islands formed in the Northern Hemisphere a kind of net, which detained the masses of earth gradually removed from the North Pole ; while in the Southern Hemisphere such a network would be wanting. We now see why the increase of the land in the Southern Hemisphere took place so much nearer to the equator than in the Northern Hemisphere. It is clear that the transportation of land by means of icebergs is not, taken by itself, a sufficient explanation ; but I have already shown that submarine transportation, by means of the Polar currents, is another potent factor in this connection, and these two processes, taken together, amply suffice to account for the removal of masses of land from the poles to the equator. This leads me to conclude that the first continents, in the geological sense of to-day, were probably Polar countries, perhaps originating through the collection of large masses of water in the equatorial zone, due to the centrifugal force engendered by the rotation of our planet ; but so soon as this *terra firma* at the poles came into existence, the constant removal of land from the poles in the direction of the equator must have commenced, under the influence of the factors explained above. Thus we see that in the countries between the equator and the poles enormous sedimentary formations were heaped up, a process which is still going on.

Returning to the geographical distribution of animals, the distribution between the south polar countries and the southern points of the continents probably took place shortly after the mammals and birds began to inhabit our globe ; for only the edentates and the ostrich birds appear to me to have the South Pole as their geographical centre. During the lengthy subsequent period, the countries round the North Pole formed, so to speak, bridges for the migration of terrestrial organisms ; and this

# Map of the Globe, according to Dr. Jaeger's Method of Projection.

(Compare Dr. PETERMANN'S *Geographische Mittheilungen*, Ergänzungsheft 16).



accounts for the great number of different species of animals which occur in the countries surrounding the Northern Arctic Regions of our planet.

A glance at a map of the Polar Regions shows that not only the details of the outlines of the continents, but also the distribution of the continents themselves, depend to a great extent on oceanic action. I shall therefore now try to reconstruct certain of the conditions of the distribution of land and sea which existed in previous geological periods. If we compare the western coasts of the British Isles and Norway with their eastern coasts, we see that the former are eaten into to a large extent ; and if we enquire the causes, we must consider how far the climate, and, further, the action of the ocean, favour detrition of this kind. Meteorologists are convinced that the climates of Great Britain and Norway are greatly influenced by the Gulf Stream, which raises the temperature and increases the quantity of moisture in these parts of Europe, thus producing a zone of considerable and variable atmospheric moisture, such as is a necessary factor for the process of detrition of the land. Hence, I think it safe to assert that all the coasts which are under the influence of those northern branches of the Gulf Stream are gradually being decomposed, and that in an earlier period the corresponding coast-lines were situated much further to the west. Several North Pole expeditions of recent times have confirmed the fact that the Gulf Stream makes its influence noticeable even beyond 80° N.L. ; and we may therefore assume that this gradual retreat of the coasts of Europe took place on the whole western line, even as far as Spitzbergen. In order to be able to estimate the amount of this loss in Europe, we have first to consider that, within the territory touched by the Gulf Stream, the amount of detrition increases with the geographical latitude, as the action of cold winters, and the destructive effect of glaciers and icebergs, is enhanced accordingly. That this is the case has been proved by actual observations. Now, if the Gulf Stream exercises a destructive influence on the Western coast of Europe, the transportation of the land thus destroyed, by means of the submarine current called the Anti-Gulf Stream, must first be taken into consideration. Let us assume, to simplify matters, that in earlier times land existed connecting Norway with Spitzbergen, and the latter with

Greenland, thus forming a large gulf, corresponding in shape to that of the Gulf of Mexico. In this case, the full force of the Gulf Stream must have acted on the Scandinavian coast; and in the most northern corner of this gulf the Gulf Stream must have changed its direction, forming now the Anti-Gulf Stream. The greater part of the latter flows underneath the Gulf Stream, in a south-westerly direction, and its presence has been established beyond dispute, by taking measurements of the temperature. But as the Gulf Stream makes its influence principally felt on the Scandinavian coast, the Anti-Gulf Stream is pushed aside, and flows southward near the eastern coast of Greenland, where it is noticeable as a cold current. How have these two currents acted on the coast of our assumed Arctic Gulf? The Gulf Stream produces a moist and warm climate, favourable to the detrition of the coast, and thus the latter becomes gradually disintegrated. Hence, the rotating motion of the currents gradually transports masses of earth from the British Isles and Scandinavia in the direction of Greenland, and thence to Newfoundland. The east coast of Greenland, however, does not profit by this transport of material, for the Anti-Gulf Stream near this coast is cold, and thus the climate of the eastern coast of Greenland is likewise very cold, the consequence being the formation of glaciers, and the removal of land by means of icebergs. The result is, that not only from the coast of the British Isles and of Norway, but also from the coast of Greenland, a large amount of solid material is carried away towards the south, and deposited further down; and that this is no hypothesis, but an actual fact, is, *e.g.*, proved by the presence of Newfoundland and its sandbanks.

From all these observations, I have come to the conclusion, that in a previous geological period a continent existed connecting Greenland with Europe. This land has been destroyed by the Gulf Stream, and the enormous mass of detritus now lies in the depths of the Atlantic Ocean. If we study a map which shows the depth of the North Atlantic Ocean, we find that shallow water exists right across, from Rockall over the Azores to a point 20° N.L. and 57° W.L. from Greenwich, in the direction in which the submarine part of the Anti-Gulf Stream flows. This submarine elevation is surrounded to the right and to the left by

depths which average 1,000 fathoms below its surface. If we calculate approximately the volume of this elevation, including the banks of Newfoundland, the result is about 26,000 cubic miles (German). This accounts for the quantity of land eaten away between Ireland, Norway, Spitzbergen, and Greenland, which I calculate to amount to 21,000 German cubic miles of material. We must therefore regard Greenland and the Scandinavian Peninsula as the last branches of a continent which, according to the distribution of plants and animals, must still have been in existence during the tertiary period, and which I will call the *Arctis*. Its destruction, as we have seen, was principally caused by the action of the Gulf Stream.

We owe to the Darwinian theory that the zoology of to-day deals with a number of problems which can only be solved with the aid of geography and palæontology. If it is correct that all animals and plants have a common origin, dating from the earliest periods of the history of our planet, and if this state of things has been greatly influenced by the geographical changes and limitations of the animal kingdom, we see that the geographical distribution of animals now living is, together with palæontology, one of the most important guides which we possess to the genealogical connection of organisms. The discovery of new species is, of course, not the principal object of geology in the Arctic regions, because the number of species is naturally limited there. A much more important task is to trace the distribution of animals, and, in connection therewith, to institute comparative palæontological researches. In investigating those animals which live on *terra firma*, and which have not, like the birds, the capacity of crossing large sheets of water, we notice at once the peculiarity that the distribution of all animals belonging to the vertebrate or invertebrate groups is arranged according to the parallel circles of the globe. So far, nobody has paid special attention to this arrangement, which has hitherto been supposed to be based on the need of equable annual temperature. No doubt, this is one of the most important conditions of existence for animals, as well as for plants, and it explains why the territories of distribution have, as a rule, a larger extension from east to west than from south to north. But the fact that we have quite a

number of terrestrial animals, which, in similar families, inhabit at the same time the corresponding geographical latitudes of the old, as well of the new, world, separated by the Atlantic and by the Pacific Oceans, is not explained by the factor mentioned. We find that the centres of these circular arrangements of distribution can only lie in or near the two poles ; and that only the North Pole can be considered as the centre of certain groups, *e.g.*, bears, bisons, reindeer, and so on. If we add that the so-called cosmopolitan genera of animals in the Northern Hemisphere show much smaller differences between the animals of the old and the new world than in the Southern Hemisphere, we see plainly that the North Pole, and not the South Pole, is the centre of most of these circles. The question is, how have we to explain the central position of the North Pole countries, with reference to the fauna of terrestrial animals ? I am of opinion that there is no other explanation than that the progenitors of these animals inhabited, in a previous geological epoch, the country near the North Pole, which was equally connected with the old and with the new world, and that, owing to changes in the climate of these territories, this whole fauna circularly expanded in the direction of the equator ; a number of considerations point to the fact that these changes in climate were several times repeated. Hence, we have, in the circular distribution of the animals round the North Pole, the last remnants of an old North Pole fauna. This assumption is favoured by the fact that, on those islands which, like the New Siberian Islands, surround the north polar sea, as well as on the northern coast of Siberia, the remnants of mammoth, rhinoceros, and other fossil animals have been found ; and the occurrence of lignite on the northern coast of Spitzbergen is a further indication of the previous habitability of the Polar countries. Moreover, a glance at the map shows that, if this view is correct, extensive changes in the distribution of the land in these regions must have taken place since the time when this boreal fauna was displaced from its original territories. The circular distribution of nearly all terrestrial animals round the North Pole has led me to the conclusion that the previous boreal fauna was likewise circularly distributed ; and I am therefore of opinion that we have here to deal, not with the north polar continent, but with the shores of a

Polar sea. *For these reasons I incline to believe that no land, but an ocean, will be found at the North Pole.**

I am further of opinion that this polar basin must, in a previous geological age, have been surrounded by land on all sides, similarly to the Mediterranean Sea of to-day. But, in all probability, there was one spot where communication with the more southern seas existed, as a great many large rivers discharge their waters into the polar basin ; I believe that this communication was effected by means of the Behring Straits, which were for the polar basin what the Straits of Gibraltar are for the Mediterranean Sea ; and I am therefore not inclined to believe that at this spot the fauna of the old and of the new world mingled with one another. I am led to the conclusion that the lands surrounding the polar sea were then connected on the opposite side, viz., between Norway and Greenland, by a large tract of *terra firma*, and I have already given in the present chapter the reasons for this belief.

If we now try to reconstruct this extinct continent, we find a Polar sea, open near to the Behring Straits, its shores inhabited by a rich fauna of terrestrial animals ; and if we assume that this was the distribution of the north polar land and seas during the tertiary period, we have a complete explanation of the distribution of the Polar animals of to-day. I am aware that this explanation is at the present time hypothetical, and has only a certain amount of probability in its favour ; but I believe that the question will be solved by one of the polar expeditions which, from time to time, try to penetrate the mysteries of the yet unknown polar basin.†

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* This interesting view, propounded by *Dr. Jaeger* in the year 1865, has been disregarded by geographers until, quite recently, its correctness has been proved by *Dr. Nansen's* discovery of a deep Polar sea round the North Pole.—THE ED.

† The correctness of this anticipation has been proved by *Dr. Nansen's* eventful Journey, 1893—1896.—THE ED.

# XXXII.—ON THE DIFFERENT STATES OF AGGREGATION OF MATTER.*

(1885.)

LIFE is motion. Inertia is death. Whoever seeks to understand life must be acquainted with the motions of matter, without which the mass is dead—a *moles*. The acknowledged scientific view—theoretical, indeed, but harmonizing with the facts—is that all substances are in the first place composed of homogeneous particles, termed molecules, each being capable of movements, which are called molecular movements. These movements are diverse, and take place in all bodies, even in such as are fixed and apparently motionless ; among the best-known instances are the expansion and contraction of wood and iron, through changes in the temperature. In connection with these molecular movements, it will be sufficient for our purpose to establish the following rule : the movement of the molecules in matter may be active or weak, the degree of activity representing the vital force of matter (a question of the first importance in the study of life), while matter without molecular movement is an inanimate *moles*. The impossibility of movement without space is a primary induction from the well-known fact, that matter of which the molecular movement has been enhanced by heating (heat is molecular movement) demands, with elementary force, increased space ; as also that heated matter possesses greater power than similar matter in a cold condition. Let us take water as an example. If we heat it, we see its internal movement

* When *Crookes* and *Hittorf* discovered the so-called radiant matter, we became aware that high dilutions of gases by no means extinguish the physical forces of matter, but that, under certain circumstances, the converse takes place. Professor *Röntgen's* astonishing results, in connection with *Crookes'* and *Hittorf's* discoveries, have further shown the great importance of the study of the different states of aggregation. *Dr. Jaeger* has approached the subject from quite a separate point of view, which, in connection with the researches of the three other scientists, will probably lead to further important discoveries; and this interesting chapter is therefore included in the present volume.—The Ed.

augment ; we all know that water in a heated condition expands, and that its powers of dissolving and distending are greater than when in a cold state. Additional heating converts water into steam, which requires enormously increased space, although there is no augmentation of bulk or weight, and the specific effects of water in the form of steam are more powerful than those of equally hot water. These facts show irrefutably that force is something which, like matter, requires space ; and that when matter acquires force through heating, it must have space in which to expand.

We now come to the question of dilution, and it is important to remember that the expansion of matter is coincident with its rarefaction. Steam is rarefied water, which has not only lost none of its force through rarefaction, but has enormously gained. Rarefaction is therefore not synonymous with diminution of force ; on the contrary, the force of matter cannot be enhanced without rarefaction, *i.e.*, without the movement asunder of the molecules.

We now take the opposite case, viz., that in which matter is rarefied without force being imparted to it. Here the question arises as to whether the rarefaction, *i.e.*, the moving asunder of the molecules, results in enhanced force or not. This is answered by every text-book in the affirmative, as follows : heat is motion or force. When, therefore, a body is caused to expand, so that its molecules move asunder, the latter attract, with elementary power, heat, *i.e*, motion, from their surroundings. The sundered molecules extract this force or motion, in the form of heat, from all contiguous objects. The physicist expresses this by saying that whenever rarefaction takes place, heat becomes latent. This law holds good with both methods of rarefaction ; heat becomes latent, or, in other words, frigidity is induced, when a gas is rarefied under the air pump (practical use is made of this law in the manufacture of ice) ; lower temperatures are also obtained when any solid matter, for instance, salt, is dissolved in a fluid (this plan is also employed for making ice). That the heat which disappears (becomes latent) through rarefaction of matter is not really annihilated, is proved by the contrary experiment, inasmuch as the heat reappears (becomes evident) so soon as the original state is restored from the rarefied state. The best known example in this respect is that the weather becomes warmer directly snow falls, that is, so

soon as water passes from the form of rarefied vapour to that of solid crystals. The same thing happens to a fluid if the salt which it contains is crystallized out of it, and to a gas when it is compressed. The question whether latent heat signifies an increase of force in matter must also be answered in the affirmative; for latent heat means molecular motion, which does not, indeed, affect the thermometer, but is of great importance in living bodies. This latent heat exists in two different forms :—

*Firstly*, in a pendulous movement, by means of which the molecules fill up the intermediate spaces caused by the rarefaction. That this movement cannot be measured with the thermometer is clearly shown by the following comparison : let us imagine a number of pendulums, with even movement, suspended on a wall at such intervals that, in swinging towards each other, they just touch, but do not come into collision ; and that the stroke of the pendulum at the extreme end reaches directly to a second wall, standing at right angles to the first. The position of the second wall with regard to the pendulums resembles that of the thermometer in respect of the pendulous molecules. The internal movement becomes evident, however, so soon as the pendulums are brought nearer together, say to the extent of a fourth of the original intervening distance. The pendulums then seek to traverse a route which is four times longer than that which is at their disposal, and thus three-fourths of the original movement has become superfluous ; this, in the pendulum experiment, will make an impression on the second wall, and, in the case of molecular motion, on the thermometer. Another question is whether the swinging together of the molecules, which does not affect the thermometer, is otherwise ineffective. That this is certainly not the case may be shown by continuing the pendulum experiment. It is clear that each new body, for instance, each new pendulum, which is introduced between the swinging pendulums, is exposed to the full force of the pendulous movement. It is the same with the molecules whenever, for instance, two solutions of a matter are mingled, especially if the solutions are of the same matter, but of different degrees of concentration. The molecules of the weaker solution, moving with greater freedom than those of the more concentrated solution, must cause the latter to be acted on by the

former. Further, just as, in the pendulum experiment, more movement is imparted to the air by the pendulums swinging in it than if the pendulums were absent, so the pendulous motion of the molecules of salts in a saline solution increases the molecular movement of the solution.

*Secondly*, another form of what physicists term latent heat is the revolving of the molecule on its axis, the intensity and rythmus depending on the specific nature of the molecule, *i.e.*, on its chemical composition. This specific movement, termed by physicists *specific heat*, is also enhanced by rarefaction, *i.e.*, the moving asunder of the molecules; and a portion of the heat which has become latent is employed in the increase of this motion. The latent state of this revolving of the molecule on its axis, *i.e.*, the fact that it cannot be measured with the thermometer, is very easily accounted for: the molecules can only act upon the thermometer when their regular movement is in excess of the molecular distance, for then they "strike" against the molecules of the thermometer. No such effect could proceed from the revolving of the molecule on its axis. On the other hand, it is just as clear that the absence of effect on the thermometer by the revolving of the molecule on its axis does not imply impotence in every direction. The best proof of this is the effect of such movements on our chemical senses, *i.e.*, taste and smell; and physiologists are unanimous that of all the perceptions of the senses those of smell and taste are most felt and ingrained, and therefore the most vitally important. We may express it thus: the rarefaction of a matter enhances its molecular force, especially its specific animating force.

Let us now sum up. In the question of the relations between matter, force, and space, we have distinguished two cases. If we now take these together, we arrive at the following: just as matter to which we communicate force, *i.e*, molecular movement (by heating), forcibly acquires space in which to achieve this movement, so a substance whose molecules we have moved asunder by expansion acquires the necessary molecular motion to fill out the intervening space, *i.e.*, it increases its force. Force and matter thus act as rivals in respect of space. The more matter, the less force (*i.e.*, motion) is available in a given space; and the more motion we desire to have in a given space, the less matter can be

permitted to occupy the space. There are other facts which throw light on the behaviour of the molecules of a dissolved matter, and which may be thus stated : if, for instance, 100 grammes of common salt be dissolved in 900 grammes of water, the molecules of salt are expanded over a space ten times larger than they previously occupied. As their number is not increased, this means ten times as much space in which to move ; and the question is merely whether or no the molecules use it to accomplish movements. That they do so is proved by the phenomena of what is termed Diffusion.* If, for instance, a vessel containing a 10 per cent. saline solution be connected by a tube with another vessel holding only water, the molecules of salt begin at once to migrate into the latter, and do not rest until the solution in both vessels has reached an equal degree of concentration. The case may be put thus : a matter dissolved in a solution has an infinite tendency to expand therein, and therefore behaves like a gaseous body. That the molecules of salt in a solution move even beyond the solution itself, is shown by the fact that the dissolved substance can be smelled in the air which is stationary over the solution. A further undisputed proposition is, that the dissolved matter is equally distributed, and everywhere present, in a solution. This could not be the case if the molecules were to remain immovable at the intervals of distance induced by the rarefaction ; and their ubiquity is only rendered possible through their filling up the intervals between their neighbours by the above-mentioned pendulous movement. The question now arises, whether these movements become proportionately more animated when, by additional rarefaction, the distance between the molecules is increased. This may be answered in the affirmative, both from experiments and from daily practical experience. The experiment of gas rarefaction, under the air pump, shows that every augmentation of rarefaction caused fresh quantities of heat to disappear, and the same is the case if we further rarify a solution of salt.

Let us now gather up the threads, returning again to the saline solution. To produce chemical, *i.e.*, mass-effects, much acts on much ; but we must employ a rarefied solution—and the more rarefied the

* See chapter XV.

better—in order to increase the tendency of the molecules to disperse; as, for instance, when it is desired to stimulate the movement of a body rendered sluggish by an excess of salt. By using as rarefied a solution as possible, the movement of the salt is stimulated, without increasing its bulk. This can be shown by a simple calculation: in a ten per cent. solution of common salt, one tenth of the space is occupied by the salt itself, and nine tenths by the movement of the salt molecules; the mass and the motion stand thus in the relation of one to nine. In a one per cent. solution, a hundredth part of the space is taken up by the mass of the salt, and ninety-nine hundredths by the molecular movement. Thus, in the one per cent. (*i.e.*, rarefied) solution, there is eleven times as much molecular movement of salt as in the the ten per cent. (*i.e.*, concentrated) solution.

In conclusion: life is motion—molecular motion. The study of life therefore gravitates to the study of motion, *i.e.*, of physics, particularly molecular physics. Chemistry, which bases its study on matter, is powerless alone to deal with the study of life. This is no mere theoretical assertion, but a fact which has been abundantly proved in practice, as well as in science.

# GLOSSARY.

NOTE.—*The Medical definitions and terms have chiefly been taken from* DR. GOULD'S *well-known Medical Dictionary.*

**Acephala.**—Headless molluscs.

**Actinia.**—A genus of Polyps, animals with soft bodies which may enormously extend by means of imbibition.

**Adaptation.**—In biology, the capacity of acquiring new characters.

**Albumin.**—A proteid substance, one of the principal constituents of the body; the molecule of Albumin is highly complex, and varies widely, within certain limits, in different organs and conditions. Albumen, the white of egg, is largely composed of it.

**Albuminates.**—The compounds of Albumin, and certain bases.

**Albuminoids.**—Substances resembling true proteids in their origin and composition. They are amorphous, non-crystalline colloids, occurring as organized constituents of the tissues, and in fluid form.

**Albumin Peptone.**—*See* Peptones.

**Amoebæ.**—Protoplasmatic organisms constantly undergoing changes of form, and feeding on surrounding objects. *See* Rhizopodes.

**Amoeboidal Motion.**—Changes of form of the Amoebae, consisting of protrusions and shrinkages of their substance.

**Amphioxus.**—A vertebrate animal, differing from all other vertebrates in that it is without head, brain, or extremities; all its organs are much simpler than those of the higher vertebrates. The Amphioxus is one of the most important factors in favour of the Darwinian theory, especially from the embryological point of view. Its organisation is so humble that the first specimen discovered was believed to be a slug, and was described as *Limax lanceolatus.*

**Anthozoa** (*i.e.*, **Corals**).—A group of Zoophytes.

**Anti-Gulf Stream.**—A submarine current, of which the greater part flows underneath the Gulf Stream, in a S.W. direction.

**Aphonic Period.**—A period in the development of the human race, as well as of the human individual, preceding the development of language.

**Arctis.**—A hypothetical continent of the tertiary period, of which Greenland and the Scandinavian peninsula are regarded as the last remnants. Its destruction is assumed by *Dr. Jaeger* to have been principally caused by the action of the Gulf Stream.

**Atlas.**—The uppermost of the cervical vertebræ.

**Bivoltine Species.**—Species producing two generations in the course of one year.

**Blastula.**—Term used in embryology, indicating a hollow globe, the wall of which is composed of a single layer of cells.

**Brachiopoda.**—One of the great subdivisions of molluscs.

**Calcareous Sponges.**—One of the divisions of the sponges. The living species of Calcareous Sponges have a skeleton composed of spicula of lime, and *Haeckel* has proved their great variability of species.

**Capitulum.**—A general term applied to any protuberance of bone received into the hollow part of another bone.

**Cartilagenous Fishes.**—Fishes having the internal skeleton in a state of cartilage or gristle, the bones containing little or no calcareous matter.

**Cephalopodes.**—A group of molluscs characterized by a distinct head surrounded by a circle of long arms or tentacles, used for crawling, and seizing objects.

**Cervical Vertebræ.**—Seven (constituting the neck) of the thirty-three bones forming the spine or vertebral column in man.

**Chemical Immunity.**—According to *Naegeli* and *Jaeger*, it obtains when an organism has previously been attacked by an infectious disease, and is due, according to *Jaeger*, to the fermentation products of fungi.

**Chitin.**—The substance which gives firmness to the tegumentary system of many articulate animals.

**Chondrigen.**—The fundamental substance of gristle.

**Chorda-dorsalis.**—A cellular cord enclosed in a structureless sheath, which, in the embryo, finally develops into the vertebral column.

**Chorion.**—The enveloping membrane of the foetus.

**Ciliata.**—A group of the lowest animals, consisting of single cells. Their surface is covered with fine hairs or cilia.

**Coelenterata (often termed Animal-Plants or Zoophytes).** A group of the animal kingdom containing, among others, the sponges, polyps, comb-jellies, and corals (Anthozoa).

**Collagen.**—The fundamental substance of bone.

**Comb Jellies (Ctenophoræ).**—A group of jelly-fishes, with either spherical, cylindrical, or ribbon-shaped bodies. They have peculiar, comb-like organs, capable of voluntary motions.

**Crinoides.**—A group of echinoderms, in which the body is attached, during the whole or part of the animal's existence, to the bed of the sea by means of a jointed, flexible stalk.

**Ctenophoræ.**—*See* Comb Jellies.

**Cytodes.**—According to *Haeckel*, the simplest forms of organic life; they are mere pieces of germ-plasma.

**Dehydration.**—The diminution of water in the tissues of an organic body.

**Diaphysis.**—The middle part of the long cylindrical bones.

**Diffusion.**—The passing of a substance into the space occupied by another.

**Dorsal Vertebræ.**—Twelve of the thirty-three bones forming the spine or vertebral column in man.

**Edentates.**—An order of mammals nearly destitute of teeth.

**Emydin.**—A white nitrogenous substance contained in the yolk of turtles' eggs.

**Entoderma.**—The inner of the two layers of cells which form the body of the gastrula.

**Epigenesis.**—The generation of organisms by new and successive formations.

**Epiphysis.**—An on-growth of bone attached to another bone by cartilage.

**Epistropheus.**—An old name for the Atlas or first vertebra of the neck ; also applied to the second vertebra, which coalesces with the first vertebra, or Atlas.

**Exoderma.**—The outer of the two layers of cells which form the body of the gastrula.

**Fibrine.**—An albumin or proteid ; a substance which, becoming solid in shed-blood, plasma, and lymph, causes coagulation of these fluids.

**Flagellata.**—A group of the protozoa, furnished with whip-like organs used as a means of locomotion.

**Foraminifera.** —*See* Rhizopodes.

**Fundamental Biogenetic Law.**—*See* Phylogeny.

**Ganglion.**—A centre of the nervous system containing nerve cells, receiving and giving out impressions.

**Ganoid Fishes.**—A group of fishes, the essential character of which is that they have ganoid scales, these being generally of an angular form and composed of horny or bony plates covered with a thick layer of enamel. The endo-skeleton is cartilagenous.

**Gastral.**—Pertaining to the stomach or abdomen.

**Gastrula.**—According to *Haeckel*, an embryonal form of all animals above the Protozoa. *Haeckel* regards it as the most important embryonal stage of the animal kingdom.

**Globulin.**—A native proteid.

**Haemoglobin.**—A substance existing in the corpuscles of the blood, to which the red colour of the latter is due.

**Holoblastic Eggs.**—Animal eggs which, in the process of egg-cleavage, are separated by repeated divisions into a large number of cells.

**Holothuriæ.**—A maritime group of echinoderms, characterised by their more or less worm-like appearance. They live at the bottom of the sea.

**Hydro-diffusion.**—Diffusion when both substances are in a liquid state.

**Ichthydin.**—An albuminous substance obtained from fishes.

**Imbibition.**—Diffusion of liquids in solid substances. It is one of the most characteristic properties of all substances forming animal or vegetable tissues. Every substance of this kind is capable of imbibing a certain quantity of liquid.

**Invertebrate.**—Having no spinal column.

**Irritability.**—The quality of being susceptible to excitement or irritation; muscular irritability is the inherent quality of a muscle, and nervous irritability is the capacity of a nerve to transmit an impulse after receiving a stimulus.

**Keratogenous.**—Pertaining to the formation of horny growth.

**Lecithin.**—A class of nitrogenized, phosphorized substances occurring in brain- and nerve-tissue.

**Lordo-Neurula.**—The modification of the neurula stage, in which the gastral and the neural folds are not diametrically opposed to each other.

**Lumbar Vertebræ.**—Five in number (in Man), constituting part of the spinal column between the dorsal vertebræ and the os sacrum.

**Macrocephalia.**—Excessive development in size of the head. A systematic deviation in a genus or species distinguished by abnormally large heads.

**Marasmus.**—A gradual deterioration of the physical and mental forces of the body.

**Materia Peccans.**—A term used to designate substances in the body injurious to its functions.

**Meroblastic Eggs.**—Animal eggs which possess a nutritive yolk, and, in the process of egg-cleavage, separate into a number of cells.

**Mesodermatic Layer.**—The layer which originates between the two primary layers of the gastrula (exoderma and endoderma),

**Metagenesis.**—A term used to denote the series of changes in organic development, commonly known as alteration of generation.

**Microcephalic.**—Having a small head.

**Molecular Motions.**—Motions of the molecules which take place within the infinitely small spaces which separate the molecules from one another. The effects of molecular motions are noticeable in many observations, but, so far, the molecular motions themselves have only been indirectly observed.

**Monadines.**—A family of Rhizopodes of the order Flagellata.

**Monera.**—A group of minute marine rhizopodes, including some of the lowest forms of life.

**Morula.**—An ontogenetic stage produced by the repeated cleavage of cells, thus forming a globe-like heap of cells, resembling a mulberry.

**Nephritis.**—Inflammation of the kidneys.

**Neural.**—Pertaining to nerves.

**Neurula.**—The neural fold formed in the ontogenetic development of the higher animals.

**Nuclein.**—An albuminoid substance.

**Onomatopoeia.**—The formation of words in imitation of the sounds made by the things signified.

**Ontogeny.**—The history of the development of the individual, from the ovum until death.

**Ortho-neurula.**—The modification of the neurula, in which the neural fold is diametrically opposed to the gastral fold.

**Os Sacrum.**—Part of the spinal column. In the human skeleton it consists of five vertebræ, forming a single bone.

**Pangenesis.**—A. biological hypothesis, according to which every unit or cell in the body throws off gemmules, or undeveloped germs, which are transmitted to the offspring of both sexes, and are multiplied by self-division.

**Parthenogenesis.**—The successive generations of organisms which procreate without direct fertilization.

**Pelvis.**—The cavity of the inferior part of the trunk containing the urinary and genital organs.

**Peptones.**—A class of animal proteids produced during digestion. The Peptones are the chief sources of energy, and of repair of waste, in the animal economy.

**Perigenesis of the Plastidula.**—A hypothesis of *Haeckel*, according to which the smallest parts of living plasma have undulatory motions which are in direct connection with propagation and inheritance.

**Periosteum.**—A tough connective tissue surrounding bones.

**Peritonitis.**—Inflammation of the membrane which lines the interior of the abdominal cavity and surrounds the viscera.

**Phylogeny.**—Development of an animal species in the long course of geological periods. The important so-called biogenetic law is, that the ontogenetic development of the individual is a short repetition of the phylogenetic development of the species.

**Plastidula.**—According to *Elsberg* and *Haeckel*, the smallest part of living plasma.

**Plastidula-Soul.**—The animal soul, based, as regards its material substratum, on the plastidula.

**Pleuritis.**—Inflammation of the serous membrane which envelopes the lung, commonly called pleurisy.

**Polynoe.**—A maritime worm, occurring in European seas.

**Proteids.**—A general term for the albumins and albuminoid constituents of the organism.

**Protein.**—A nitrogenous substance analogous to fibrine.

**Protists or Proto-ontes.**—Unicellulates of the lowest organization, intermediate between animal and vegetable kingdoms.

**Protoplasm or Sarcode.**—The fundamental substance of organic cells, which has the power of forming new cells ; considered by many biologists as the physical basis of life.

**Pseudopodia.**—Organs of locomotion and prehension in some of the lowest animal organisms.

**Rhizopodes.**—A class of the Protozoa, containing individuals with the power of emitting pseudopodia. The class is divided into four orders :—Monera and Amoebæ ; Foraminifera ; Radiolaria ; and Heliozoa.

**Sarcode.**—Identical with Protoplasm.

**Sauropsida.**—The combined groups of reptiles and birds.

**Sea-Nettles.**—The group of Acalephæ or Medusas. The body is of a soft gelatine-like substance.

**Specific Heat** is the quantity of heat required to raise the temperature of a body of given weight, *e.g.*, 1 kilogramme, by 1°, the unit of measure being the quantity of heat required to raise the same weight of water to the same temperature.

**Synkinesis.**—Involuntary movement in one part of the body in consequence of a voluntary, or reflex, movement in another part.

**Thorax.**—The part of the body enclosed by the ribs and the breastbone.

**Tuberculosis.**—An infectious disease, commonly called consumption, in which the lungs are the seat of a specific bacillus characterized by the formation of tubercles.

**Urea.**—The chief constituent of urine, and the principal and final nitrogenous product of the metamorphosis of tissue.

**Vacuoles.**—Small spaces within cell-protoplasm, containing a clear fluid.

**Vitellin.**—A native proteid of the globulin class ; the chief proteid of the yolk of egg.

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